A Comparative Analysis of Productivity Growth and Productivity Dispersion: Microeconomic Evidence Based on Listed Firms from Japan, Korea, and China

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Utilizing the firm-level dataset, this study aims to explore differences in firm-level productivity and growth between Japan, Korea, and China. Our main results can be summarized as follows. First, although Japanese firms enjoy the highest average TFP level in many industries, their TFP growth rate has been relatively low during the past two decades. Korean firms have achieved considerable TFP growth in certain industries. The average TFP level of Chinese firms is still much lower than that of Japanese and Korean firms in many industries. Second, within-industry dispersion of TFP levels is very small for Japanese firms. Third, in Korea, the TFP levels of low-performing firms are approaching those of the national frontier firms at a more rapid pace than in Japan.

Keywords: Total factor productivity, Micro data, TFP growth, Productivity dispersion, Listed firms, Japan, Korea, China

JEL Classification: D24, L25, O53, O57

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I. Introduction

East Asia's dramatic economic growth post World War II has been widely characterized as nothing short of a miracle, the determinants and effects of which have been examined and analyzed by academics, business practitioners, and governments alike. The pattern of economic development in the region has been frequently described in terms of the "Flying Geese" paradigm, with Japan the first to achieve rapid economic growth, followed by Korea and the other newly-industrializing economies (NIEs), the Association of South East Asian Nation (ASEAN) countries, and finally China (Kojima 2003). However, although Japan continues to be the most advanced country in the region in terms of total factor productivity (TFP) in a large number of manufacturing industries,[1] in certain industries, other Asian countries are already more productive than Japan. Moreover, in recent years, Japan's economic growth rate has been outpaced by its East Asian neighbors, suggesting that the productivity gap between Japan and the rest of East Asia is shrinking (Motohashi 2005).

Many previous studies have investigated the convergence or divergence of macro- or industry-level productivity performance in an attempt to discover the sources of economic growth. At the macro level, previous studies underline the role of technological progress, human capital, institutions, and market structure in explaining the economic performance of different countries and industries (Barro and Sala-i-Martin 2004; Hall and Jones 1999, *etc.*). More recently, utilizing micro data, the divergence or convergence of productivity among firms has been intensively scrutinized, providing us with insights into the mechanisms underlying productivity convergence or divergence across countries. The large body of literature on micro-level productivity has shown that firms' managerial ability, use of technology, human capital, competitive pressure, and technology diffusion or spillovers are

[1] According to Motohashi (2005), China's, Korea's, and Taiwan's relative TFP levels were lower than Japan's in most industries in 1995. However, in non-electrical machinery, the TFP gap between Japan and Korea, at approximately 4%, was very small, while Taiwan's TFP level in fact was higher than Japan's by 14%. On the other hand, in the fabricated metal sector, the Korean TFP level was 28% higher and the Taiwanese TFP level was 4% lower than Japan's.

important determinants of productivity levels and productivity growth.[2] On the other hand, empirical studies focusing on the connection between aggregate and micro productivity growth have examined the contribution of resource reallocation across firms to aggregate productivity growth, based on the idea that aggregate productivity grows faster if more inputs and output are allocated to high-productivity firms and less to low-productivity firms.

However, the number of micro-level productivity analyses from an international comparative perspective is very limited.[3] Most recent micro-level studies compare productivity levels or growth within a country or examine whether non-frontier firms within the country are catching up with national frontier firms. Unfortunately, such studies on individual countries remain silent on whether productivity across countries is converging, since they cannot identify the global technology frontier that is the hypothesized source of knowledge spillovers. However, a small number of pioneering works on the international comparison of productivity and firm dynamics based on micro data do exist, such as Bartelsman, Scarpetta, and Schivardi (2003) and Bartelsman, Haltiwanger, and Scarpetta (2004, 2005), which attempt to explore the country-specific factors that affect aggregate patterns of productivity growth. Although the coverage of the data sets of these studies differs across countries, they do manage to compile comprehensive firm-level data covering almost all firms in manufacturing and other industries. Unfortunately, however, Japan and China are not analyzed in these studies. Although Korea is included in the study by Bartelsman, Haltiwanger, and Scarpetta (2004, 2005), no TFP analysis for Korea is conducted.

In 2006, the Japan Center for Economic Research launched a research project on the "Comparison of the Productivity of

[2] For a comprehensive literature survey on this issue, see Bartelsman and Doms (2000).

[3] In contrast, there have been extensive international productivity comparisons at the industry or macro level, conducted by the EU KLEMS project (see http://www.euklems.net) and at the Groningen Growth and Development Centre at the Economics Department of the University of Groningen (see http://www.ggdc.net). A comparative study of East Asian countries has been conducted by the ICPA (International Comparison of Productivity Among Asian Countries) project at RIETI (Research Institute of Economy, Trade and Industry) in Japan (see http://www.rieti.go.jp/jp/database/data/icpa-description.pdf).

Japanese, Chinese, Korean and European Firms," which aims at developing a methodology for TFP comparison in an international context and also at investigating patterns of productivity growth and convergence across countries at the micro-level. As members of this project, we compiled firm-level data to examine whether and how firm-level TFP growth characteristics differ in Japan, Korea, and China. Although our firm-level dataset is limited to listed firms, as far as we know, this is the first comprehensive comparative study on firm-level TFP in these countries.

These three East Asian countries are still at different stages of economic development, although they achieved industrialization one after another as explained by the "Flying Geese" hypothesis mentioned above. Utilizing the dataset we constructed, this study specifically aims to explore differences in productivity and growth between Japan, Korea, and China, while at the same time illuminating the mechanism that has driven the narrowing in the productivity gap that can be observed and will be described in detail below. In this study, we pursue two strategies. First, we compare the firm-level TFP distribution of major industries in these three countries over time to examine catch-up patterns within and across industries. Second, in order to examine patterns of technology diffusion across these three East Asian countries, we conduct a regression analysis on TFP convergence to the national frontier and to the global frontier.

However, we should note that our analysis is limited to listed firms in these countries and we cannot say that the performance of listed firms represents industry- or macro-level economic performance. Particularly in China, most foreign-owned firms are not listed; yet, foreign-owned firms are generally considered to be a major driving force of economic development and technology upgrading in the country. But even with these shortcomings, this comparative study is meaningful for the following reasons: (1) it is the first study which compares TFP levels among these countries based on firm-level data; (2) as listed firms tend to be large and more representative of each country, an international comparison focusing specifically on listed firms may in fact be more meaningful; put differently, given the differences in economic development, it is difficult to compare very small firms in a developing country with firms in a developed country; and (3) using firm-level data for listed firms allows us, at least in the case of Japan and Korea, for which sufficient data are available, to examine TFP performance over a long period of time.

Our main results can be summarized as follows. First, although Japanese firms enjoy the highest average TFP level in many industries, their TFP growth rate has been relatively low during the past two decades. On the other hand, Korean firms have achieved considerable TFP growth in certain industries, and in the electrical and general machinery industries, their TFP growth has outpaced that of Japanese firms in recent years. The average TFP level of Chinese firms is still much lower than that of Japanese and Korean firms in many industries. Second, within-industry dispersion of TFP levels is very small for Japanese firms when compared with Korean and Chinese firms. Comparing time-series data for Japan and Korea, we find that in both countries the within-industry dispersion of TFP levels has been expanding in many industries. However, while the within-industry ranking of TFP levels hardly changes in the case of Japan, fluctuations in the ranking are relatively frequent in the case of Korea. In Japan, higher-performing firms tend to remain at a higher ranking and lower-performing firms tend to remain at a lower ranking for a long period. Third, in Korea, the TFP levels of low-performing firms are approaching those of the national frontier firms at a more rapid pace than in Japan.

The remainder of this paper is organized as follows. Section II describes the characteristics of our firm-level data sets and compares firm- and industry-level TFP for Japan, Korea, and China. In Section III, we investigate the TFP dispersion within an industry, while in Section IV, we conduct an econometric analysis to explore the TFP convergence mechanism in these three countries. Section V concludes and makes suggestions for the future direction of international comparative studies on productivity growth and convergence.

II. Firm- and Industry-Level TFP for Japan, Korea, and China

A. Data

In this section, we first describe the major characteristics of listed firms in Japan, Korea, and China based on our firm-level dataset. We then examine the firm- and industry-level TFP growth for these three countries, focusing on several major industries.[4]

We construct the firm-level TFP measure using annual financial data for the period 1985-2004 for Japan and Korea and for the period 1999-2004 for China.[5] Table 1 summarizes the number of firms in each industry and country.[6] We should note the following drawbacks of our dataset. First, because there is no information on the year of listing and delisting for Korea and China, we identified firms which were delisted during our sample period using various data sources. Although we were able to identify the year of delisting for all Korean firms, we were only partially successful in the case of Chinese firms. Second, the Korean database includes historical financial data for firms which were listed as of 1990 and therefore does not include data for firms which were delisted before 1990. This may be a possible reason why the number of Korean firms delisted during the period 1985-1995 is zero. Third, for Korean firms listed after 1990, the database includes the financial data before the listing if the firm was "sufficiently large."[7] Therefore, for Korean firms, we should interpret the "entry" to the stock market as the time when the firm size became "sufficiently large" (see footnote 7). In the case of Chinese firms, approximately 20 out of the 87 firms which exited the stock market are confirmed

[4] We calculate each firm's TFP based on the index number method of Good, Nadiri, and Sickles (1997), taking the year 1999 as the base period. For an explanation of our methodology of constructing a TFP measure that is comparable across countries, see Fukao *et al.* (2008).

[5] We were not able to calculate TFP for China before 1999 due to data constraints. For the TFP calculation, we exclude observations whose output or input data are negative or missing. Moreover, we exclude outliers whose calculated TFP level is larger (smaller) than the country-industry-year average plus/minus three standard deviations. However, we do not exclude such outliers in the case of China because of the small sample size for China.

[6] Outliers are excluded from the numbers presented in Table 1.

[7] However, the threshold size of "sufficiently large" firms differs from year to year. Before 1988, the database includes financial data for firms whose total assets exceeded 3 billion won or whose capital exceeded 0.5 billion won. The database includes financial data for firms whose total assets exceeded 3 billion won for the years 1988-1990, 4 billion won for the years 1990-1993, 6 billion won for the years 1993-1998, and 7 billion won for years after 1998. However, several firms which do not meet these criteria are included in the database.

TABLE 1

NUMBER OF LISTED FIRMS AND FIRM TURNOVER

(a) Japan		1985	1985-1995		1995	1995-2004		2004
		No. of Firms	Entry	Exit	No. of Firms	Entry	Exit	No. of Firms
1	Agriculture	2	2	0	4	0	1	3
2	Coal mining	3	0	0	3	0	0	3
3	Metal and nonmetallic mining	2	0	0	2	0	0	2
4	Oil and gas extraction	3	0	0	3	3	1	5
5	Construction	143	83	4	222	38	45	215
6	Food and kindred products	98	46	1	143	28	15	156
7	Textile mill products	50	4	2	52	1	8	45
8	Apparel	22	10	0	32	2	6	28
9	Lumber and wood	6	5	0	11	0	2	9
10	Furniture and fixtures	7	5	0	12	2	2	12
11	Paper and allied products	32	7	3	36	6	12	30
12	Printing, publishing, and allied products	10	17	0	27	17	3	41
13	Chemicals	156	58	4	210	31	22	219
14	Petroleum and coal products	10	0	0	10	1	2	9
15	Leather	1	2	0	3	0	0	3
16	Stone, clay, and glass products	64	27	8	83	8	13	78
17	Primary metals	98	17	4	111	6	24	93
18	Fabricated metals	56	44	0	100	10	14	96
19	Non-electrical machinery	178	70	2	246	28	41	233
20	Electrical machinery	156	88	2	242	79	38	283
21	Motor vehicles	83	28	0	111	16	14	113
22	Transportation equipment and ordnance	28	4	0	32	2	8	26
23	Instruments	32	19	0	51	13	8	56
24	Rubber and misc. plastics	39	28	0	67	10	9	68
25	Misc. manufacturing	16	28	0	44	18	5	57
26	Transportation	104	38	3	139	13	17	135
27	Communication	2	4	0	6	16	1	21
28	Electrical utilities	9	1	0	10	2	0	12
29	Gas utilities	12	1	0	13	3	1	15
30	Trade	212	337	13	536	222	89	669
31	Finance, insurance, and real estate	23	30	2	51	61	12	100
32	Other private services	70	192	2	260	421	28	653
33	Public service	1	0	0	1	0	0	1

(Table 1 Continued)

(b) Korea	1985	1985-1995		1995	1995-2004		2004
	No. of Firms	Entry	Exit	No. of Firms	Entry	Exit	No. of Firms
1 Agriculture	5	1	0	6	0	0	6
2 Coal mining	1	0	0	1	0	0	1
3 Metal and nonmetallic mining	0	0	0	0	0	0	0
4 Oil and gas extraction	0	0	0	0	0	0	0
5 Construction	44	14	0	58	4	3	59
6 Food and kindred products	48	10	0	58	8	1	65
7 Textile mill products	19	8	0	27	2	1	28
8 Apparel	18	11	0	29	7	3	33
9 Lumber and wood	3	1	0	4	1	0	5
10 Furniture and fixtures	4	0	0	4	1	0	5
11 Paper and allied products	25	8	0	33	0	0	33
12 Printing, publishing, and allied products	1	4	0	5	12	0	17
13 Chemicals	101	38	0	139	32	2	169
14 Petroleum and coal products	4	1	0	5	0	0	5
15 Leather	5	5	0	10	2	1	11
16 Stone, clay, and glass products	28	2	0	30	5	0	35
17 Primary metals	42	26	0	68	10	1	77
18 Fabricated metals	15	20	0	35	8	3	40
19 Non-electrical machinery	28	45	0	73	57	7	123
20 Electrical machinery	71	133	0	204	169	21	352
21 Motor vehicles	32	25	0	57	13	1	69
22 Transportation equipment and ordnance	7	1	0	8	2	0	10
23 Instruments	8	15	0	23	14	0	37
24 Rubber and misc. plastics	14	12	0	26	11	1	36
25 Misc. manufacturing	5	4	0	9	3	1	11
26 Transportation	18	2	0	20	3	0	23
27 Communication	3	3	0	6	4	0	10
28 Electrical utilities	1	0	0	1	0	0	1
29 Gas utilities	10	1	0	11	0	0	11
30 Trade	44	28	0	72	29	2	99
31 Finance, insurance, and real estate	0	0	0	0	0	0	0
32 Other private services	15	59	0	74	151	7	218
33 Public service	0	0	0	0	0	0	0

(Table 1 Continued)

(c) China		1999	1999-2004		2004
		No. of Firms	Entry	Exit	No. of Firms
1	Agriculture	13	14	3	24
2	Coal mining	4	8	1	11
3	Metal and nonmetallic mining	3	2	0	5
4	Oil and gas extraction	2	2	0	4
5	Construction	9	11	3	17
6	Food and kindred products	29	25	1	53
7	Textile mill products	17	13	2	28
8	Apparel	6	6	1	11
9	Lumber and wood	0	0	0	0
10	Furniture and fixtures	1	1	0	2
11	Paper and allied products	10	7	0	17
12	Printing, publishing, and allied products	2	2	0	4
13	Chemicals	106	81	7	180
14	Petroleum and coal products	9	5	1	13
15	Leather	1	1	0	2
16	Stone, clay, and glass products	26	23	3	46
17	Primary metals	25	25	1	49
18	Fabricated metals	8	4	1	11
19	Non-electrical machinery	46	28	4	70
20	Electrical machinery	84	51	10	125
21	Motor vehicles	17	17	2	32
22	Transportation equipment and ordnance	13	6	0	19
23	Instruments	7	4	0	11
24	Rubber and misc. plastics	9	11	0	20
25	Misc. manufacturing	8	7	2	13
26	Transportation	22	26	4	44
27	Communication	21	19	4	36
28	Electrical utilities	21	19	2	38
29	Gas utilities	4	2	1	5
30	Trade	60	21	9	72
31	Finance, insurance, and real estate	46	17	21	42
32	Other private services	30	12	4	38
33	Public service	0	0	0	0

to have been delisted. However, there are others which were dropped from our dataset due to missing variables. Therefore, we should note that in the case of China, the number of exited firms in our dataset does not necessarily correspond to the number of firms that actually did delist from the stock market.

Looking at Table 1, it can be seen that in most industries, the number of Japanese firms in our dataset is larger than that of Korean or Chinese firms. Moreover, in the case of Japan, the number of exited firms increased in the period from 1995-2004 compared to 1985-1995. For some industries, the number of observations, particularly observations of Korean and Chinese firms, is extremely small. Therefore, in our productivity analysis we focus on the following 12 industries with a relatively large number of observations: construction; food and kindred products; textile mill products; apparel; paper and allied products; chemicals; stone, clay, and glass products; primary metal products; non-electrical machinery; electrical machinery; motor vehicles; and transportation.

Table 2 compares the average size of firms by industry and country. We use the number of employees per firm and the total assets per firm as measures of firm size. In Table 2, the columns labeled "cross country average" show the average size of firms for all three countries. The three following columns then show the ratio of the average size of firms in each country to the three-country average. Therefore, the average firm size in a particular country is larger than the three-country average if the ratio is greater than 1. As we can see from Table 2, Chinese firms are the largest in terms of employment, while Japanese firms are the largest in terms of assets.

Table 3 shows the number of firms by stock market. In Japan, stock markets are divided into a first section for relatively large firms, a second section for smaller firms, and markets for start-ups such as the JASDAQ market.[8] Moreover, following the amendment of stock trading laws, new stock exchange markets for start-up firms such as Hercules and Mothers were established at the end of the 1990s. Similarly in Korea, there are two stock markets: the KSE for relatively large firms and the KOSDAQ, founded in 1996, for start-up firms.[9] In China, there are the Shanghai Stock Exchange and the Shenzhen Stock Exchange. As shown in Table 3,

[8] In 2001, the over-the-counter market was renamed the JASDAQ market. In Table 3, "JASDAQ" refers to the over-the-counter market in 1985 and 1995.

[9] Although the KOSDAQ was founded in 1996, there exist firms listed on the KOSDAQ before 1996. This is because our database contains historical financial data for relatively large firms as mentioned above.

TABLE 2

WITHIN-INDUSTRY AVERAGE FIRM SIZE FOR 2004:
AS A SHARE OF CROSS-COUNTRY SECTORAL AVERAGE

		Number of employees per firm				Total assets per firm			
		Cross country average	Japan	Korea	China	Cross country average (mil. US$)	Japan	Korea	China
1	Agriculture	3,024	0.13	0.18	**1.31**	207	**1.19**	0.66	**1.06**
2	Coal mining	8,771	0.04	0.04	**1.35**	375	**1.49**	0.54	0.91
3	Metal and nonmetallic mining	2,128	0.05	n.a.	**1.38**	173	**1.30**	n.a.	0.88
4	Oil and gas extraction	44,641	0.01	n.a.	**2.24**	7,223	**0.22**	n.a.	**1.98**
5	Construction	1,217	**1.03**	0.51	**2.37**	974	**1.15**	0.63	0.41
6	Food and kindred products	1,505	0.62	0.68	**2.50**	688	**1.38**	0.57	0.40
7	Textile mill products	1,530	0.57	0.22	**2.47**	490	**1.83**	0.24	0.42
8	Apparel	1,520	0.33	0.24	**4.97**	210	**1.34**	0.47	**1.73**
9	Lumber and wood	544	**1.11**	0.80	n.a.	320	**1.17**	0.69	n.a.
10	Furniture and fixtures	1,154	0.95	0.46	**2.66**	406	**1.43**	0.34	0.27
11	Paper and allied products	1,116	0.81	0.25	**2.79**	671	**2.09**	0.30	0.43
12	Printing, publishing, and allied products	846	**1.24**	0.27	**1.61**	638	**1.48**	0.08	0.12
13	Chemicals	1,422	0.74	0.38	**1.89**	642	**1.93**	0.48	0.36
14	Petroleum and coal products	3,767	0.18	0.40	**1.80**	2,196	**1.47**	**1.81**	0.36
15	Leather	666	0.33	0.39	**5.38**	149	**2.06**	0.55	**1.91**
16	Stone, clay, and glass products	1,400	0.57	0.38	**2.20**	536	**1.43**	0.74	0.47
17	Primary metals	2,372	0.50	0.28	**3.09**	1,118	**1.53**	0.56	0.71
18	Fabricated metals	696	0.88	0.44	**4.05**	345	**1.22**	0.40	**1.22**
19	Non-electrical machinery	1,110	**1.08**	0.20	**2.14**	606	**1.64**	0.14	0.37
20	Electrical machinery	1,595	**1.13**	0.38	**2.44**	769	**2.03**	0.36	0.48
21	Motor vehicles	3,192	**1.15**	0.57	**1.41**	1,795	**1.58**	0.39	0.23
22	Transportation equipment and ordnance	2,419	0.31	**2.25**	**1.29**	862	0.62	**3.45**	0.23
23	Instruments	729	**1.20**	0.33	**2.20**	389	**1.66**	0.21	0.31
24	Rubber and misc. plastics	1,106	0.90	0.56	**2.14**	565	**1.44**	0.41	0.55
25	Misc. manufacturing	629	0.88	0.36	**2.07**	444	**1.28**	0.18	0.49
26	Transportation	2,862	**1.11**	0.67	0.85	2,065	**1.26**	0.67	0.37
27	Communication	2,304	0.66	**2.05**	0.91	3,512	**2.24**	**1.23**	0.18
28	Electrical utilities	4,786	**2.18**	**3.78**	0.56	9,788	**3.48**	**5.82**	0.09
29	Gas utilities	1,327	**1.31**	0.42	**1.33**	1,707	**1.46**	0.76	0.15
30	Trade	834	0.88	0.61	**2.67**	768	**1.14**	0.54	0.34
31	Finance, insurance, and real estate	688	0.66	n.a.	**1.81**	1,069	**1.23**	n.a.	0.38
32	Other private services	714	0.93	0.33	**6.11**	248	**1.22**	0.34	0.94
33	Public service	85	1.00	n.a.	n.a.	116	1.00	n.a.	n.a.

Notes: 1) n.a. = not available.
2) Total assets are presented in U.S. dollar terms. Values of total assets in local currency are converted to values in U.S. dollars using market exchange rates at year-end.
3) Figures exceeding one are shaded.

TABLE 3
NUMBER OF FIRMS BY STOCK MARKET

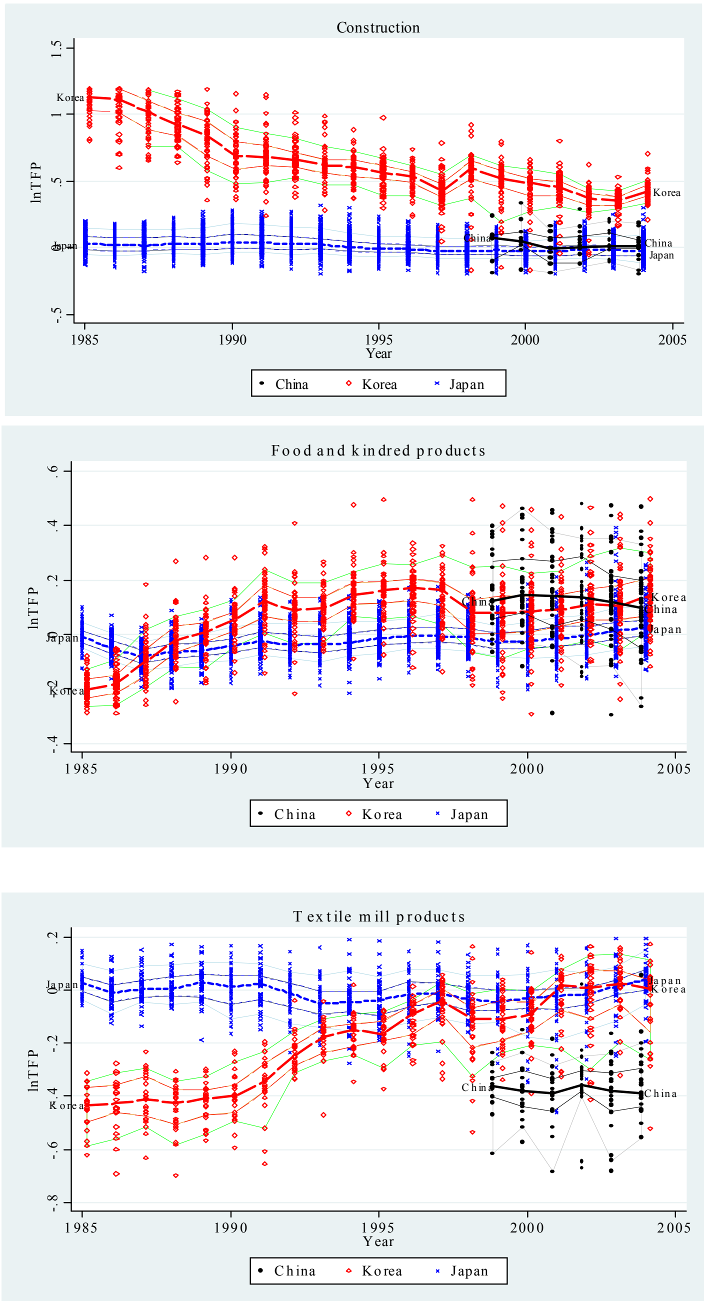
	1985	1995	2004*
Japan: Total	1,728	2,873	3,521
1st Section	1,029	1,322	1,558
2nd Section	373	634	805
JASDAQ	0	465	908
Other	0	0	230
Korea: Total	619	1,096	1,563
KSE	485	545	613
KOSDAQ	134	551	950
China: Total	n.a.	n.a.	1,042
Shanghai	n.a.	n.a.	641
Shenzhen	n.a.	n.a.	401

Notes: 1) * Data are for 2005 in the case of Korea.
2) n.a. = not available.

the number of listed firms in Japan, and especially that of firms listed in the Second Section and on JASDAQ, has increased remarkably. In Korea, the number of firms listed on KOSDAQ exceeds that of firms listed on the KSE, probably reflecting the fact that the number of start-up firms has increased very rapidly in recent years. In China, the number of firms listed on the Shanghai Stock Exchange is larger than that of firms listed on the Shenzhen Stock Exchange.

B. TFP Trends in Major Industries in Japan, Korea, and China

Next, let us look at the distribution of firm-level TFP by industry and the trend of median TFP levels for each industry (Figure 1). For all 12 industries in Figure 1, Japanese firms show the smallest dispersion of TFP within each industry when compared with Korean and Chinese firms. Moreover, for Japanese firms, the median TFP level has been almost flat in all industries except the electrical machinery industry. On the other hand, in the case of Korea, the median TFP level as well as the overall TFP distribution have been shifting upwards in industries such as textile mill products, apparel, non-electrical machinery, electrical machinery, motor



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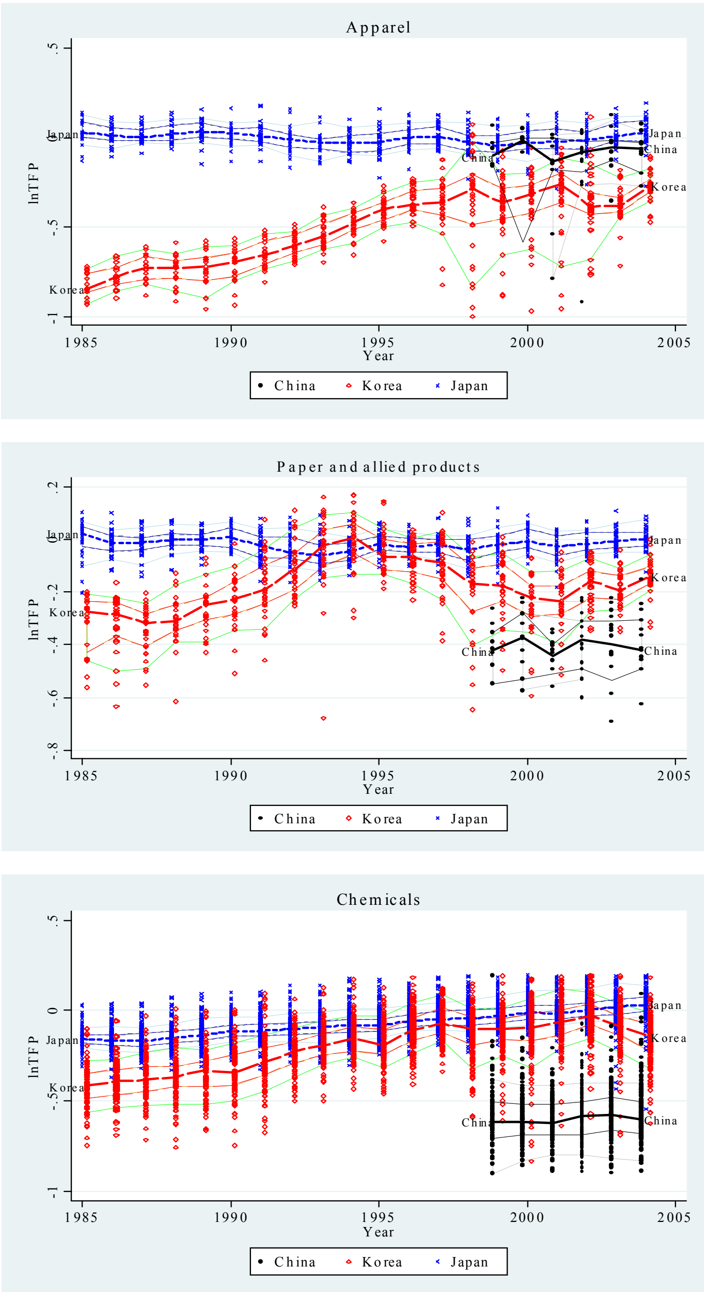

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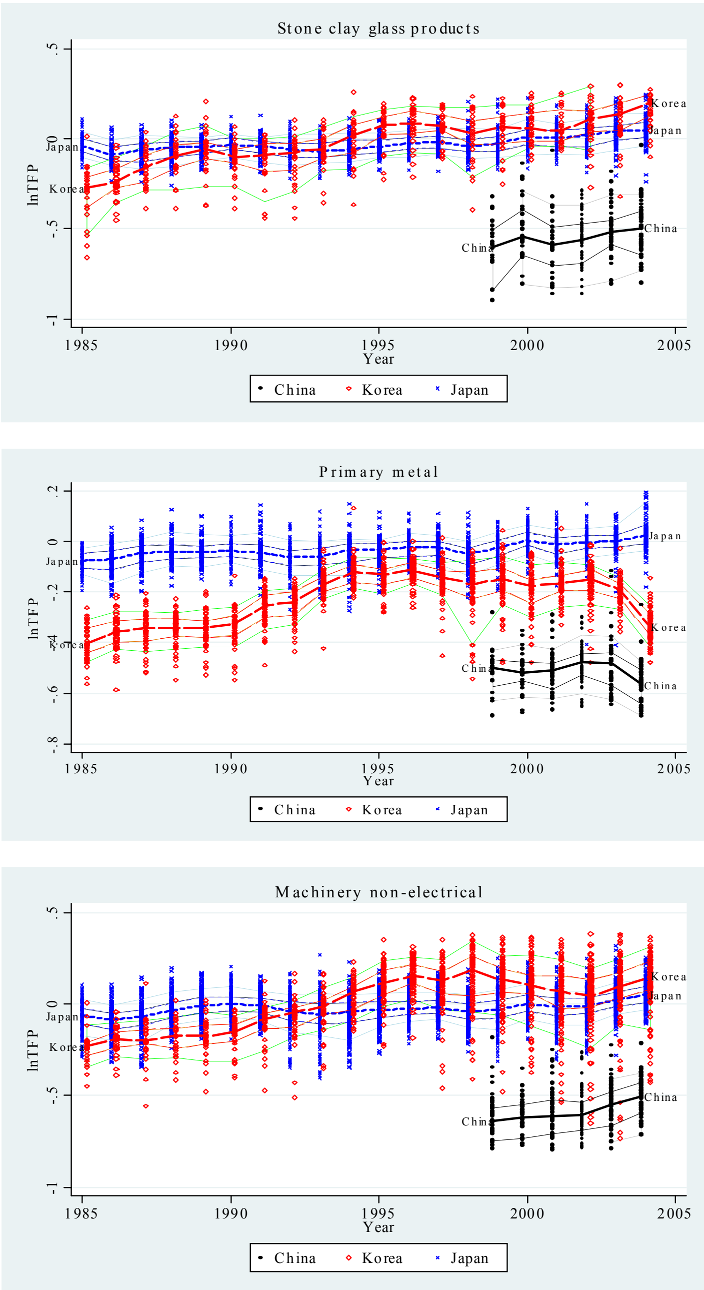

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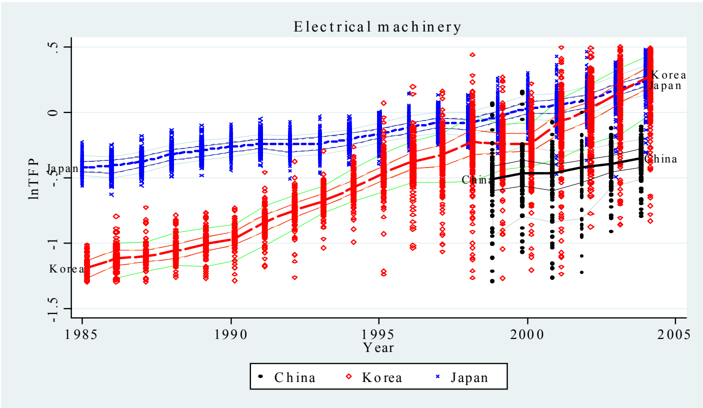
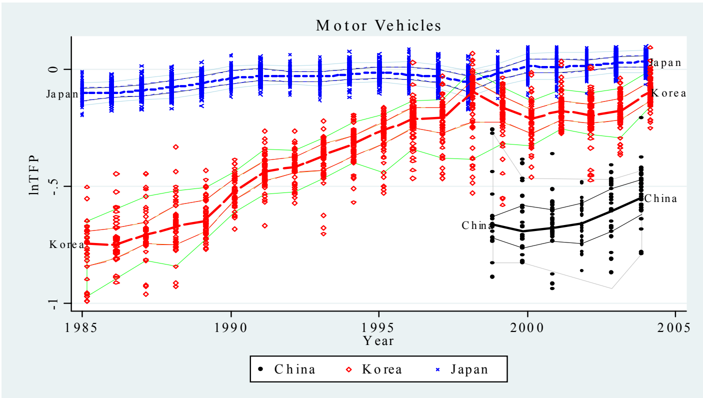




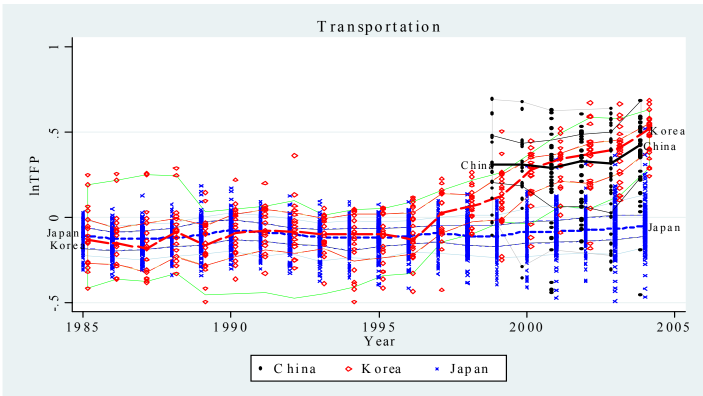


FIGURE 1

DISTRIBUTION OF FIRM TFP AND TREND OF THE MEDIAN TFP LEVEL vehicles, and transportation. As a result, the Korean median TFP level has caught up with or surpassed the Japanese median TFP level in the textile mill products and electrical machinery industries. In chemicals and motor vehicles, the Korean median TFP level had caught up with the Japanese median TFP level but more recently has fallen behind again. In the stone, clay and glass products and the non-electrical machinery industries, the Korean median TFP level has been higher than that of Japan since the mid-1990s. In the transportation industry, Japanese TFP has been stagnating, whereas Korean TFP has been increasing since the mid-1990s, so that in recent years it has been much higher than Japanese TFP.

The median TFP of Chinese firms is much lower than that of Japanese and Korean firms in most industries, with the exception of apparel and transportation. Although it is believed that the technological capabilities of the machinery industries in China have been improving and the production of high-tech machinery parts and components has been increasing, the overall TFP level of Chinese listed firms in the sector is still much lower than that of Japanese and Korean firms. A possible explanation for this is that technological progress has been largely led by foreign-owned firms, most of which are not listed on Chinese stock exchanges and therefore not included in our dataset. Chinese stock markets were under full control by the government until 2000, and only firms assigned by the government had been able to get listed. Therefore, many Chinese listed firms are former state-owned enterprises and not always high performing. In the motor vehicles industry, for example, the overall TFP level of Chinese firms is significantly lower than that of Japanese and Korean firms, although our dataset includes major joint-ventures between foreign automobile manufacturers and Chinese local firms.

C. Decomposition of Industry-Level TFP for Japan, Korea, and China: Resource Allocation and Productivity

We can calculate the industry-level TFP by aggregating the firm-level TFP using the following equation (Baily, Hulten, and Campbell 1992):[10]

[10] Aggregated labor productivity is usually calculated as a weighted average of firm-level labor productivity using the employment share as a weight.

$$\ln TFP_t = \sum_f \theta_{ft} \ln TFP_{ft} \tag{1}$$

where θ_{ft} denotes firm f's sales share in year t in that industry. Equation (1), though a subscript representing industry is omitted, indicates that the industry-level TFP can be calculated as a weighted average of firm-level TFP using the sales share as a weight. Moreover, by decomposing the industry-level TFP using Equation (2) below, we can analyze the determinants of industry-level TFP growth (Olley and Pakes 1996; Bartelsman, Haltiwanger, and Scarpetta 2004, 2005):

$$\ln TFP_t = (1/N_t) \sum_f \ln TFP_{ft} + \sum_f (\theta_{ft} - \bar{\theta}_t)(\ln TFP_{ft} - \overline{\ln TFP_{ft}}) \tag{2}$$

where N_t is the number of firms in year t in that industry and the first term on the right-hand side is the simple average of firm-level TFP. The variables with an upper bar indicate the simple average of the sales share and the simple average of firm-level TFP, respectively. That is, the second term of the right-hand side is the deviation from the industry mean of the sales share multiplied by the deviation from the industry mean of firm-level TFP, which can be called the resource allocation effect. In other words, a boost in industry-level TFP is realized when firms with higher TFP hold a larger share in the industry and firms with lower TFP hold a smaller share. Moreover, the above two equations show that the resource allocation effect is the difference between the weighted average of firm-level TFP and the simple average of firm-level TFP.

For the 12 major industries analyzed here, the annual growth rate of industry-level TFP (the weighted average of firm-level TFP) and the improvement in the resource allocation effect are presented in Table 4.[11] In Japan, most industries, with the notable exception of the electrical machinery industry, show a very low level of TFP growth, although the TFP growth rate is higher for the period 1999-2004 than for other periods. In Korea, the electrical machinery industry achieved the highest TFP growth rate. Excluding the period from 1995-1999 which was affected by the economic crisis, it seems that the gap between the TFP growth rate

[11] For industry-level TFP growth rates and the improvement in the resource allocation effect for all industries, see Appendix Table 1.

of the electrical machinery industry and those of other industries has been expanding in Korea. As for China, the TFP growth rate has been relatively high for industries such as stone, clay and glass products, non-electrical machinery, electrical machinery, motor vehicles, and transportation. However, the annual TFP growth rate in the Chinese electrical machinery industry at 2.8% for the period 1999-2004 was relatively low compared with corresponding rates of 5.2% for Japan and 11.0% for Korea.

The improvement in the resource allocation effect can be calculated as the difference between the resource allocation effects at the beginning and at the end of the period. In Table 4, figures in parentheses indicate the percentage contribution of the improvement in the resource allocation effect to the annual TFP growth rate. Moreover, shaded figures represent positive contributions to the annual TFP growth rate. In both Japan and Korea, the positive effect of the improvement of allocative efficiency appears to have become more pervasive in recent years (1999-2004), which may reflect the fact that the market environment has become more competitive.[12] In Korea, however, although the positive contribution of the allocative efficiency effect has been larger in recent years, in many industries the magnitude of the TFP growth rate has been much smaller than in the earlier period (1985-95). This observation suggests that overall TFP growth has stalled in many Korean industries, although competitive pressures did ensure that TFP growth continued to some extent. It seems that, in Korea, the within-firm TFP improvement effect (the first term on the right-hand side of Equation (2)) has become smaller in recent years in many industries (the electrical machinery industry is a notable exception), which is an issue that deserves further investigation. In the case of China, we find a relatively large allocative efficiency effect in many industries. This suggests that Chinese firms can easily increase or lose sales share in the rapidly growing market. In addition,

[12] For the case of Japan, Kim, Kwon, and Fukao (2007) conducted a TFP decomposition analysis and found that the resource allocation effect was relatively small during the 1980s but has gradually increased since the mid-1990s. Their findings are consistent with our results in Table 4. In the case of Korea, after the financial crisis in the late 1990s, various structural reforms were carried out and created a more competitive market environment.

TABLE 4
ANNUAL TFP GROWTH RATE AND IMPROVEMENT OF ALLOCATIVE EFFICIENCY: MAJOR INDUSTRIES

	Japan						Korea						China	
	1985-1995		1995-1999		1999-2004		1985-1995		1995-1999		1999-2004		1999-2004	
Construction	-0.57	(-33.4)	-0.31	(29.8)	0.18	(159.3)	-4.88	(15.7)	-0.79	(185.4)	-1.06	(-29.5)	-1.74	(-105.1)
Food and kindred products	-0.04	(-13.6)	-0.21	(81.2)	1.20	(10.3)	3.78	(6.3)	-1.41	(2.0)	1.91	(45.9)	-0.29	(485.8)
Textile mill products	-0.60	(16.9)	-0.05	(-81.5)	1.56	(-5.6)	3.04	(10.4)	1.98	(20.7)	1.65	(32.3)	0.16	(191.7)
Apparel	-0.57	(-5.7)	-0.63	(-49.5)	1.00	(-21.5)	4.22	(0.1)	0.37	(-30.2)	2.65	(9.5)	0.80	(-299.3)
Paper and allied products	-0.22	(-47.7)	-0.42	(-57.3)	0.57	(20.4)	2.16	(-24.6)	-3.89	(-14.8)	1.57	(44.1)	1.47	(79.1)
Chemicals	0.81	(4.7)	1.58	(16.4)	1.94	(31.1)	2.44	(3.5)	1.98	(13.0)	-0.97	(2.2)	0.60	(32.7)
Stone, clay, and glass products	-0.20	(-64.7)	0.74	(34.9)	2.09	(30.6)	3.03	(-16.4)	0.27	(56.0)	3.48	(23.6)	3.70	(33.6)
Primary metals	0.70	(47.6)	0.69	(54.8)	1.53	(8.3)	2.78	(5.8)	-1.08	(-50.1)	-2.85	(21.4)	-0.28	(273.2)
Non-electrical machinery	0.68	(43.7)	-0.15	(-136.4)	1.78	(7.9)	3.75	(5.7)	-0.94	(-96.5)	1.65	(72.1)	2.71	(-37.9)
Electrical machinery	2.67	(5.4)	3.18	(-2.1)	5.18	(-3.9)	9.23	(21.1)	0.72	(-647.2)	11.05	(10.6)	2.83	(-43.8)
Motor vehicles	0.74	(-23.9)	0.29	(173.0)	1.13	(3.5)	4.84	(-1.0)	1.03	(-142.1)	1.39	(-38.2)	2.78	(73.1)
Transportation	1.07	(-5.8)	0.83	(64.5)	1.80	(21.5)	3.59	(-16.0)	2.64	(-133.4)	9.15	(20.0)	4.94	(72.1)

Notes: The left column for each period shows the annual TFP growth rate (%), while the figures in parentheses refer to the percentage contribution of improvements in allocative efficiency to annual TFP growth. Shaded figures indicate a positive contribution to annual TFP growth.

we should note that the small sample size and the relatively low quality of the Chinese data may produce results with large measurement errors.

III. Heterogeneity of Firms: Is Productivity Dispersion Pervasive?

In this section, we examine whether the productivity dispersion within an industry has been increasing over time. Furthermore, we analyze productivity rankings within an industry and investigate whether these rankings have changed frequently.

First, we conduct a simple regression analysis in order to check whether there has been an increase in productivity dispersion. We estimate the following equation:

$$D2575_{it} = a + b^{*}(Time\ Trend) \tag{3}$$

where $D2575_{it}$ is the distance between the top and the bottom quartile in the distribution of firm TFP levels in industry i in year *t*, or the distance between the top and the bottom quartile of firm TFP growth rates in industry *i* in year *t*. By regressing the distance on a time trend, we examine whether the productivity dispersion has been increasing year by year.[13] The regression results are shown in Table 5. However, we do not conduct this regression for China due to the small sample size.

In Table 5, the coefficient on the time trend variable is significantly positive in many industries, suggesting that the dispersion of both firm TFP levels and firm TFP growth rates has been increasing year by year. The increase in the dispersion of firm TFP levels indicates that the productivity gap between high-performing and low-performing firms has been getting wider. In the case of Japan, the dispersion of TFP levels has been widening in 15 industries compared to 4 where it has been significantly narrowing. On the other hand, in the case of Korea, the dispersion of TFP levels has been widening in 7 industries and narrowing in 5 industries. As for the dispersion of firm TFP growth rates, this has increased in many industries both in Japan and Korea. The increase in the dispersion of firm TFP growth rates can be interpreted as indicating that there are increasing ups and down in the TFP levels within an industry. Although the number of industries where we see a significant positive coefficient on the time trend variable is greater for Japan than for Korea, the magnitude of the coefficient tends to be larger in Korea. This result implies that in some industries in Korea, there were larger ups and downs in the TFP level than in Japan.

Moreover, in the majority of industries which show a widening dispersion of TFP levels, we also find a significant widening in the dispersion of firm TFP growth rates: out of the 15 industries in Japan that show a widening dispersion of TFP levels, 9 also show a widening dispersion of TFP growth rates, while in Korea it is 6 out of 7.

The observations in Table 5 remind us of the four models of evolution of productivity distribution suggested by Baily, Hulten, and Campbell (1992, p. 196, Figure 1). The first model suggests

[13] The standard deviations of firm TFP levels and firm TFP growth rates can be used instead of the distance between the first and the last quartiles. However, in order to mitigate the effect of outliers, we use the distance between the first and the last quartile.

TABLE 5

COEFFICIENTS ON THE TIME TREND

Industry	Distance of TFP level		Distance of TFP growth rate	
	Japan	Korea	Japan	Korea
1 Agriculture	0.0072 ***	0.0077 **	-0.0007	0.0044
2 Coal mining	0.0005	n.a.	0.0012 **	n.a.
3 Metal and nonmetallic mining	0.0040 *	n.a.	-0.0003	n.a.
4 Oil and gas extraction	-0.0206 ***	n.a.	-0.0111	n.a.
5 Construction	-0.0022 ***	-0.0068 ***	0.0003 **	-0.0008
6 Food and kindred products	0.0009 ***	0.0030 ***	0.0002 **	0.0015 ***
7 Textile mill products	-0.00004	0.0023	-0.00003	0.0007
8 Apparel	0.0020 ***	0.0013	0.0008 **	0.0035 ***
9 Lumber and wood	-0.0012 *	-0.0063	-0.0005	-0.0036
10 Furniture and fixtures	0.0031 ***	-0.0007	0.0006 *	-0.0006
11 Paper and allied products	0.0002	-0.0020	0.0001	0.0012
12 Printing, publishing, and allied products	0.0042 ***	-0.0273 *	0.0015 ***	-0.0043
13 Chemicals	0.0012 ***	-0.0005	0.0004 **	0.0016 ***
14 Petroleum and coal products	0.0018 ***	0.0005	-0.0002	0.0006
15 Leather	0.0024	0.0036 **	0.0032 *	0.0036 **
16 Stone, clay, and glass products	0.0005	0.0007	0.0004	-0.0002
17 Primary metals	-0.0001	-0.0003	0.0003	0.00001
18 Fabricated metals	0.0009 **	-0.0024	0.0004 **	0.0005
19 Non-electrical machinery	0.0001	0.0044 ***	0.0003	0.0034 **
20 Electrical machinery	0.0005	0.0032 ***	0.0013 **	0.0041 ***
21 Motor vehicles	0.0002	-0.0021 **	0.0003 *	-0.0003
22 Transportation equipment and ordnance	0.0001	-0.0011	0.0002	-0.0011
23 Instruments	0.0001	0.0071 ***	0.0003	0.0058 ***
24 Rubber and misc. plastics	0.0018 ***	0.0018 ***	0.0008 ***	0.0017 *
25 Misc. manufacturing	0.0024 **	-0.0004	0.0012 ***	-0.0001
26 Transportation	0.0009 *	-0.0032 **	-0.0003 *	-0.0031 *
27 Communication	0.0008	-0.0263	0.0011	-0.0193
28 Electrical utilities	0.0022 ***	n.a.	-0.0001	n.a.
29 Gas utilities	-0.0067 ***	-0.0309 ***	-0.0007	-0.0122 ***
30 Trade	0.0015 ***	0.0017	0.0007	0.0026 ***
31 Finance, insurance, and real estate	-0.0003	n.a.	-0.0012	n.a.
32 Other private services	0.0042 ***	-0.0046	0.0008 ***	0.0074 ***
33 Public service	n.a.	n.a.	n.a.	n.a.

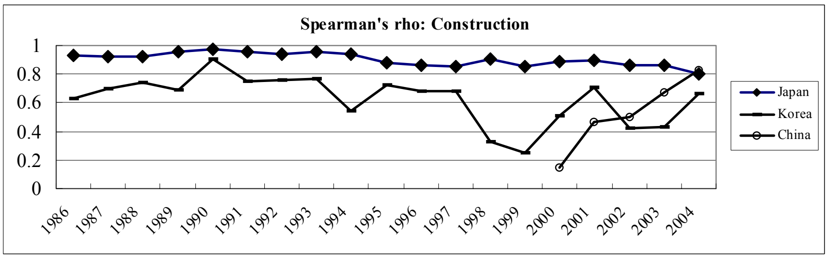
Notes: 1) Dependent variable: distance between the first quartile and the fourth quartile of the TFP level or TFP growth rate
2) The number of observations for each regression is 20 for the TFP level regressions and 19 for the TFP growth regressions.
3) n.a. = not applicable.
4) ***, **, * significant at 1%, 5%, 10%, respectively.

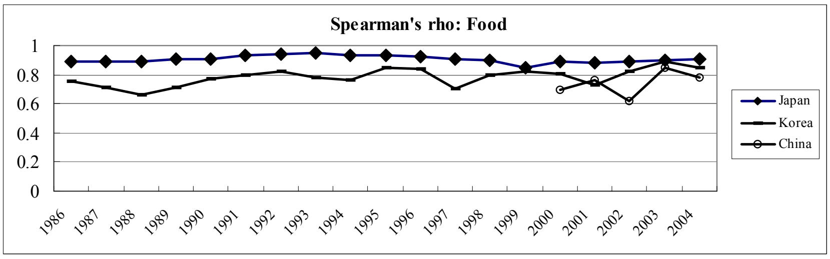
that the distribution of productivity across plants is determined by random shocks or data errors in the level of productivity, assuming the existence of a common path of trend productivity growth for all the plants in an industry. The second model attributes the distribution of productivity to a random draw in the growth of productivity rather than in the level. In the third model, the distribution arises as a result of plants of different vintages, assuming that when a plant is built it embodies a particular vintage of technology. The fourth model suggests that the distribution reflects permanent plant heterogeneity. In the remainder of this section, we analyze the rankings of firm TFP levels and their transition over time for major industries in order to identify which model best describes the pattern of evolution of productivity dispersion in the three countries.

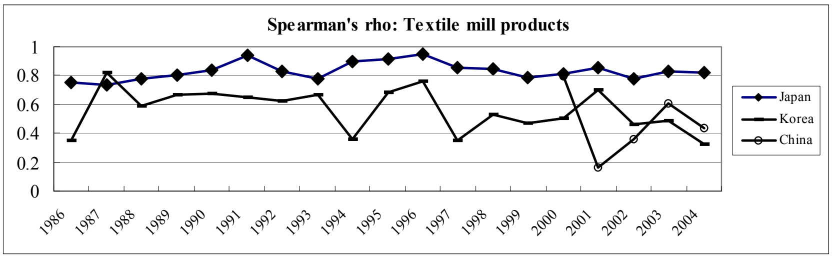
We calculate Spearman's rank correlation coefficients (Spearman's *rho*) between year $t-1$ and year t in order to examine whether firms' rankings in terms of their TFP level change frequently within an industry. If Spearman's *rho* is close to 1, this indicates that rankings in terms of the TFP level within an industry are less likely to change from year $t-1$ to t. On the other hand, a Spearman's *rho* close to zero indicates that the rankings changed almost completely. The yearly Spearman's *rho*s for the 12 major industries are shown in Figure 2. As can be seen, Spearman's *rho* is greater than 0.8 in many industries in Japan, suggesting that TFP level rankings tend to be stable. On the other hand, for Korean industries, Spearman's *rho* tends to be much smaller, suggesting frequent changes in rankings. For Chinese industries, meanwhile, Spearman's *rho* is as high as that for Japan in industries such as primary metals, non-electrical machinery, electrical machinery, and motor vehicles. These results suggest that the productivity distribution is more likely to be attributable to a random draw in the case of Korea, while it is more likely to be attributable to permanent firm heterogeneity in the case of Japan.[14]

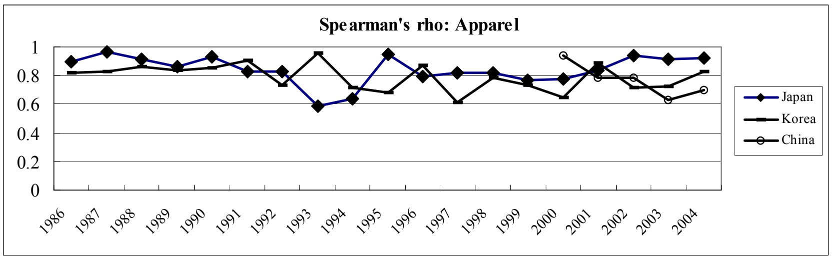
Furthermore, in order to scrutinize the change in TFP rankings, we calculate a transition matrix of the rankings for the chemical and the electrical machinery industries, where we have a relatively

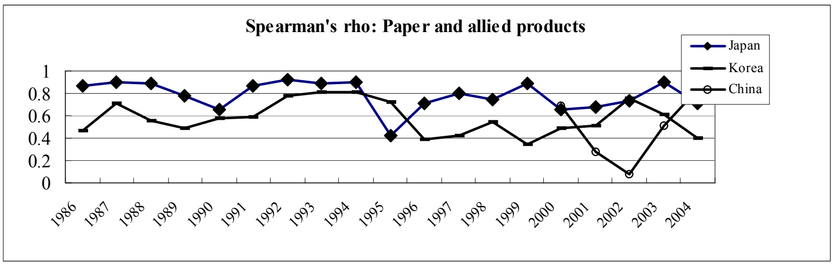
[14] It is difficult to find a clear pattern in the case of China, which may be attributable to measurement errors and the relatively small number of observations.











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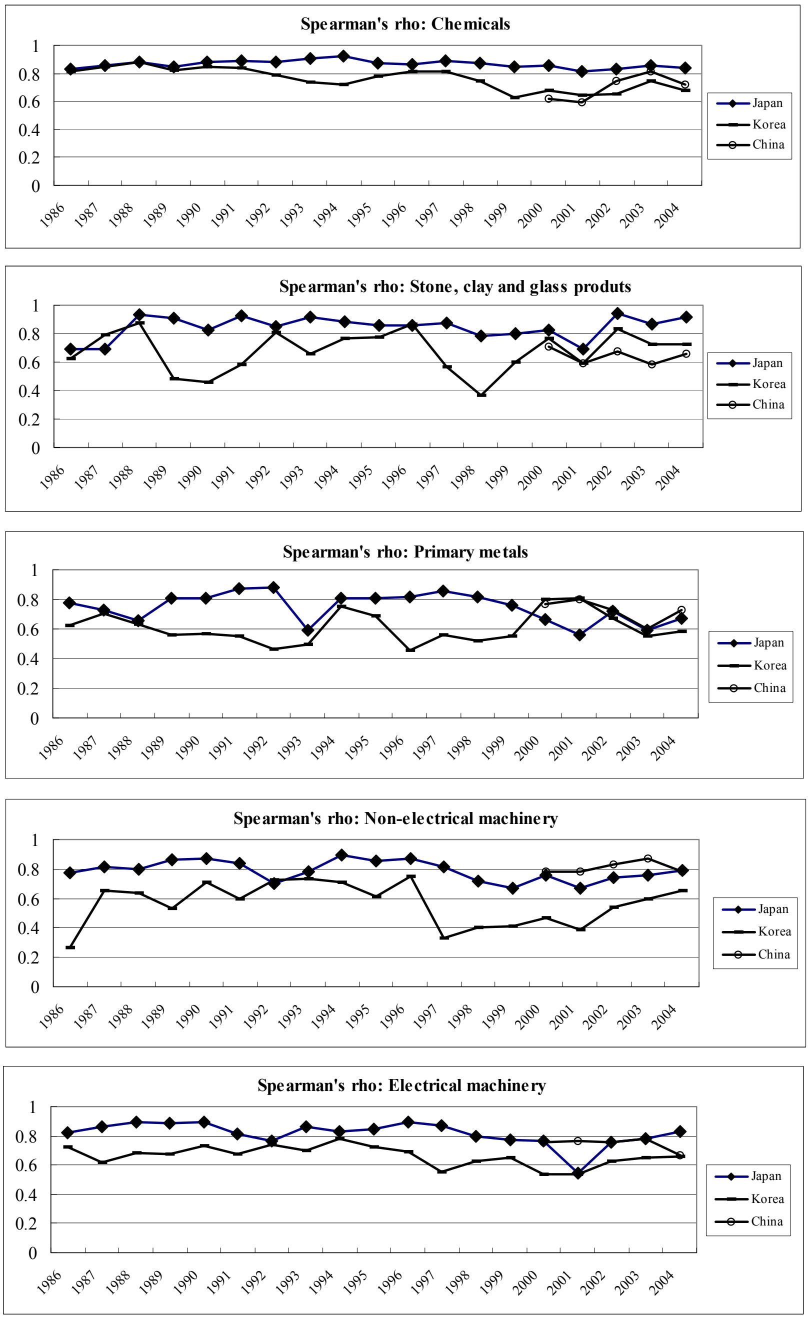

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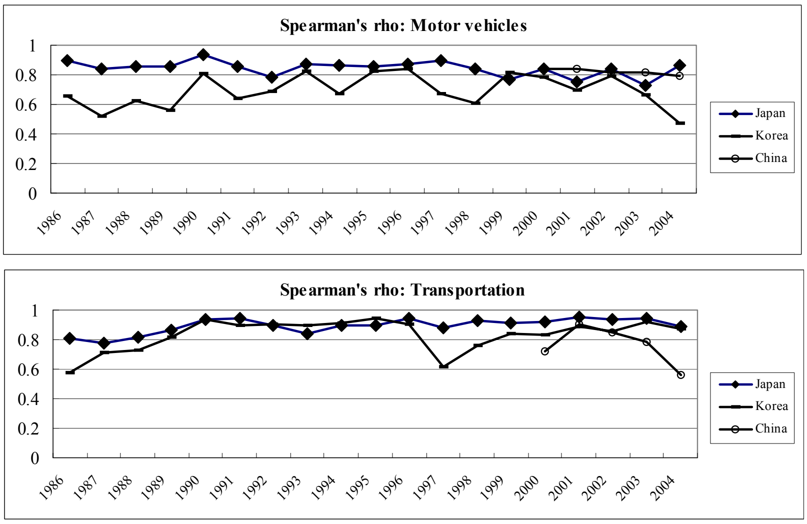

FIGURE 2
SPEARMAN'S RANK CORRELATION FOR MAJOR INDUSTRIES

large number of observations. Table 6 shows the transition matrix of the TFP rankings for three periods — 1985-1995, 1995-1999, and 1999-2004 — for Japan, Korea, and China. Hereafter, each transition matrix is denoted as A_{8595J}, A_{9599J}, A_{9904J}, and so on. The subscript J here refers to Japan, while, likewise, K and C refer to Korea and China, respectively. Each row of a transition matrix shows the decile as of the beginning of the period, while the each column shows the decile as of the end of the period. In other words, factor a_{ij} (the i^{th} row and the j^{th} column) in the transition matrix indicates the ratio of the number of firms which were in the i^{th} decile of the TFP distribution as of the beginning of the period and moved to the j^{th} decile as of the end of the period to the total number of firms which were in the i^{th} decile as of the beginning of the period. Therefore, the diagonal factors of the matrix show the share of the number of firms which stayed in the same decile during the period. The factors above the diagonal line show the share of the number of firms which moved to an upper decile while the factors below the diagonal line show the share of the number of firms which moved to a lower decile.

Looking at the transition matrices for the Japanese chemical

TABLE 6

TFP LEVEL TRANSITION MATRIXES

(a) Japan: Chemicals 1985-1995

	1995									
1985	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	33.3%	20.0%	13.3%	6.7%	0.0%	13.3%	6.7%	0.0%	0.0%	6.7%
20*th*	21.4%	42.9%	7.1%	14.3%	0.0%	7.1%	0.0%	7.1%	0.0%	0.0%
30*th*	0.0%	13.3%	13.3%	20.0%	26.7%	6.7%	0.0%	13.3%	6.7%	0.0%
40*th*	14.3%	14.3%	28.6%	14.3%	14.3%	0.0%	0.0%	7.1%	0.0%	7.1%
50*th*	14.3%	14.3%	28.6%	7.1%	14.3%	7.1%	7.1%	0.0%	7.1%	0.0%
60*th*	20.0%	13.3%	6.7%	13.3%	6.7%	6.7%	20.0%	6.7%	6.7%	0.0%
70*th*	13.3%	0.0%	6.7%	0.0%	13.3%	26.7%	26.7%	6.7%	0.0%	6.7%
80*th*	0.0%	0.0%	14.3%	14.3%	7.1%	7.1%	28.6%	28.6%	0.0%	0.0%
90*th*	0.0%	0.0%	0.0%	6.7%	13.3%	33.3%	20.0%	13.3%	6.7%	6.7%
100*th*	6.7%	0.0%	0.0%	6.7%	0.0%	13.3%	6.7%	6.7%	20.0%	40.0%

(b) Japan: Chemicals 1995-1999

	1999									
1995	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	36.8%	15.8%	21.1%	15.8%	5.3%	5.3%	0.0%	0.0%	0.0%	0.0%
20*th*	33.3%	23.8%	19.0%	9.5%	4.8%	4.8%	4.8%	0.0%	0.0%	0.0%
30*th*	5.0%	20.0%	20.0%	15.0%	20.0%	10.0%	5.0%	0.0%	5.0%	0.0%
40*th*	9.5%	14.3%	14.3%	9.5%	19.0%	9.5%	0.0%	23.8%	0.0%	0.0%
50*th*	15.8%	10.5%	15.8%	15.8%	10.5%	5.3%	10.5%	5.3%	10.5%	0.0%
60*th*	0.0%	4.8%	9.5%	14.3%	14.3%	19.0%	19.0%	9.5%	9.5%	0.0%
70*th*	5.0%	5.0%	0.0%	15.0%	10.0%	10.0%	30.0%	10.0%	10.0%	5.0%
80*th*	0.0%	5.6%	5.6%	5.6%	11.1%	11.1%	11.1%	33.3%	11.1%	5.6%
90*th*	0.0%	4.8%	0.0%	4.8%	4.8%	19.0%	14.3%	9.5%	28.6%	14.3%
100*th*	5.9%	0.0%	0.0%	5.9%	0.0%	0.0%	5.9%	0.0%	17.6%	64.7%

(c) Japan: Chemicals 1999-2004

	2004									
1999	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	27.8%	16.7%	22.2%	16.7%	0.0%	0.0%	5.6%	5.6%	5.6%	0.0%
20*th*	20.0%	20.0%	15.0%	15.0%	0.0%	15.0%	15.0%	0.0%	0.0%	0.0%
30*th*	15.8%	21.1%	5.3%	15.8%	10.5%	21.1%	5.3%	5.3%	0.0%	0.0%
40*th*	4.8%	19.0%	23.8%	4.8%	23.8%	4.8%	9.5%	9.5%	0.0%	0.0%
50*th*	0.0%	10.5%	10.5%	26.3%	10.5%	10.5%	5.3%	21.1%	5.3%	0.0%
60*th*	5.3%	10.5%	10.5%	10.5%	5.3%	15.8%	21.1%	5.3%	10.5%	5.3%
70*th*	5.0%	0.0%	10.0%	10.0%	10.0%	25.0%	15.0%	15.0%	10.0%	0.0%
80*th*	10.5%	5.3%	5.3%	5.3%	15.8%	0.0%	5.3%	26.3%	15.8%	10.5%
90*th*	0.0%	4.8%	4.8%	0.0%	23.8%	14.3%	9.5%	14.3%	23.8%	4.8%
100*th*	0.0%	0.0%	0.0%	0.0%	5.0%	5.0%	10.0%	5.0%	20.0%	55.0%

(Table 6 Continued)

(d) Korea: Chemicals 1985-1995

	1995									
1985	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	18.2%	9.1%	9.1%	18.2%	9.1%	9.1%	18.2%	0.0%	0.0%	9.1%
20*th*	10.0%	10.0%	30.0%	0.0%	0.0%	10.0%	20.0%	20.0%	0.0%	0.0%
30*th*	10.0%	20.0%	0.0%	20.0%	10.0%	0.0%	20.0%	10.0%	0.0%	10.0%
40*th*	10.0%	20.0%	0.0%	30.0%	20.0%	10.0%	0.0%	0.0%	0.0%	10.0%
50*th*	0.0%	0.0%	9.1%	18.2%	9.1%	9.1%	9.1%	27.3%	9.1%	9.1%
60*th*	0.0%	0.0%	22.2%	0.0%	22.2%	0.0%	0.0%	11.1%	44.4%	0.0%
70*th*	0.0%	0.0%	30.0%	20.0%	10.0%	10.0%	0.0%	0.0%	30.0%	0.0%
80*th*	0.0%	0.0%	10.0%	0.0%	10.0%	0.0%	20.0%	20.0%	10.0%	30.0%
90*th*	20.0%	20.0%	0.0%	0.0%	10.0%	20.0%	0.0%	10.0%	10.0%	10.0%
100*th*	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	10.0%	20.0%	30.0%	30.0%

(e) Korea: Chemicals 1995-1999

	1999									
1995	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	15.4%	38.5%	15.4%	0.0%	7.7%	7.7%	15.4%	0.0%	0.0%	0.0%
20*th*	21.4%	7.1%	21.4%	14.3%	7.1%	21.4%	0.0%	7.1%	0.0%	0.0%
30*th*	0.0%	14.3%	14.3%	21.4%	21.4%	7.1%	7.1%	7.1%	7.1%	0.0%
40*th*	7.1%	7.1%	7.1%	21.4%	14.3%	21.4%	7.1%	14.3%	0.0%	0.0%
50*th*	0.0%	7.7%	7.7%	7.7%	38.5%	15.4%	0.0%	7.7%	15.4%	0.0%
60*th*	7.7%	7.7%	7.7%	7.7%	15.4%	0.0%	15.4%	7.7%	7.7%	23.1%
70*th*	14.3%	7.1%	7.1%	14.3%	0.0%	7.1%	14.3%	28.6%	7.1%	0.0%
80*th*	7.1%	0.0%	0.0%	14.3%	0.0%	0.0%	7.1%	14.3%	21.4%	35.7%
90*th*	14.3%	14.3%	0.0%	0.0%	7.1%	7.1%	21.4%	14.3%	14.3%	7.1%
100*th*	0.0%	0.0%	15.4%	0.0%	0.0%	15.4%	23.1%	0.0%	23.1%	23.1%

(f) Korea: Chemicals 1999-2004

	2004									
1999	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	23.1%	23.1%	0.0%	7.7%	7.7%	7.7%	7.7%	0.0%	7.7%	15.4%
20*th*	20.0%	6.7%	26.7%	6.7%	20.0%	0.0%	6.7%	6.7%	6.7%	0.0%
30*th*	7.1%	7.1%	7.1%	14.3%	14.3%	21.4%	21.4%	7.1%	0.0%	0.0%
40*th*	14.3%	28.6%	7.1%	7.1%	0.0%	14.3%	14.3%	14.3%	0.0%	0.0%
50*th*	0.0%	12.5%	6.3%	18.8%	6.3%	25.0%	18.8%	6.3%	6.3%	0.0%
60*th*	7.1%	7.1%	7.1%	7.1%	35.7%	7.1%	7.1%	0.0%	14.3%	7.1%
70*th*	25.0%	12.5%	0.0%	12.5%	12.5%	6.3%	6.3%	6.3%	6.3%	12.5%
80*th*	6.7%	13.3%	20.0%	0.0%	6.7%	0.0%	20.0%	13.3%	6.7%	13.3%
90*th*	0.0%	0.0%	13.3%	0.0%	6.7%	0.0%	6.7%	26.7%	20.0%	26.7%
100*th*	0.0%	0.0%	0.0%	7.1%	0.0%	21.4%	0.0%	21.4%	21.4%	28.6%

(Table 6 Continued)

(g) China: Chemicals 1999-2004

	2004									
1999	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	14.3%	0.0%	14.3%	0.0%	0.0%	14.3%	14.3%	0.0%	14.3%	28.6%
20*th*	22.2%	11.1%	0.0%	11.1%	11.1%	44.4%	0.0%	0.0%	0.0%	0.0%
30*th*	18.2%	9.1%	9.1%	18.2%	27.3%	9.1%	0.0%	9.1%	0.0%	0.0%
40*th*	0.0%	10.0%	30.0%	10.0%	20.0%	10.0%	0.0%	20.0%	0.0%	0.0%
50*th*	0.0%	0.0%	10.0%	70.0%	10.0%	10.0%	0.0%	0.0%	0.0%	0.0%
60*th*	18.2%	9.1%	18.2%	18.2%	0.0%	9.1%	27.3%	0.0%	0.0%	0.0%
70*th*	0.0%	11.1%	11.1%	0.0%	11.1%	0.0%	22.2%	33.3%	11.1%	0.0%
80*th*	11.1%	22.2%	11.1%	0.0%	11.1%	0.0%	22.2%	0.0%	0.0%	22.2%
90*th*	22.2%	11.1%	0.0%	11.1%	0.0%	0.0%	0.0%	22.2%	22.2%	11.1%
100*th*	11.1%	11.1%	0.0%	0.0%	0.0%	0.0%	11.1%	11.1%	22.2%	33.3%

(h) Japan: Electrical Machinery 1985-1995

	1995									
1985	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	18.8%	18.8%	12.5%	12.5%	0.0%	12.5%	12.5%	6.3%	0.0%	6.3%
20*th*	26.7%	13.3%	33.3%	13.3%	6.7%	0.0%	0.0%	6.7%	0.0%	0.0%
30*th*	7.7%	23.1%	7.7%	15.4%	23.1%	7.7%	7.7%	7.7%	0.0%	0.0%
40*th*	12.5%	18.8%	6.3%	6.3%	6.3%	0.0%	12.5%	12.5%	12.5%	12.5%
50*th*	6.7%	13.3%	20.0%	20.0%	0.0%	0.0%	0.0%	6.7%	6.7%	26.7%
60*th*	0.0%	0.0%	0.0%	0.0%	26.7%	26.7%	26.7%	6.7%	13.3%	0.0%
70*th*	0.0%	12.5%	6.3%	6.3%	18.8%	0.0%	31.3%	12.5%	12.5%	0.0%
80*th*	6.7%	0.0%	6.7%	6.7%	0.0%	33.3%	13.3%	13.3%	6.7%	13.3%
90*th*	0.0%	6.7%	6.7%	20.0%	0.0%	13.3%	6.7%	26.7%	20.0%	0.0%
100*th*	0.0%	7.1%	7.1%	7.1%	14.3%	21.4%	7.1%	7.1%	7.1%	21.4%

(i) Japan: Electrical Machinery 1995-1999

	1999									
1995	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	27.3%	27.3%	9.1%	13.6%	0.0%	4.5%	4.5%	9.1%	4.5%	0.0%
20*th*	25.0%	25.0%	16.7%	0.0%	20.8%	0.0%	4.2%	8.3%	0.0%	0.0%
30*th*	22.7%	18.2%	18.2%	9.1%	9.1%	0.0%	9.1%	9.1%	4.5%	0.0%
40*th*	4.3%	17.4%	17.4%	21.7%	4.3%	8.7%	13.0%	8.7%	4.3%	0.0%
50*th*	17.4%	8.7%	21.7%	21.7%	8.7%	13.0%	8.7%	0.0%	0.0%	0.0%
60*th*	4.2%	8.3%	8.3%	8.3%	16.7%	12.5%	16.7%	16.7%	8.3%	0.0%
70*th*	4.8%	0.0%	9.5%	14.3%	19.0%	14.3%	19.0%	4.8%	14.3%	0.0%
80*th*	0.0%	0.0%	4.3%	4.3%	26.1%	17.4%	17.4%	13.0%	17.4%	0.0%
90*th*	0.0%	4.2%	0.0%	4.2%	12.5%	20.8%	20.8%	16.7%	12.5%	8.3%
100*th*	4.3%	0.0%	4.3%	8.7%	0.0%	0.0%	0.0%	4.3%	34.8%	43.5%

(Table 6 Continued)

(j) Japan: Electrical Machinery 1999-2004

1999 \ 2004	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	55.6%	5.6%	11.1%	5.6%	5.6%	11.1%	0.0%	0.0%	0.0%	5.6%
20*th*	3.8%	26.9%	19.2%	11.5%	7.7%	15.4%	0.0%	3.8%	3.8%	7.7%
30*th*	14.3%	23.8%	14.3%	14.3%	4.8%	9.5%	4.8%	4.8%	4.8%	4.8%
40*th*	9.1%	4.5%	27.3%	18.2%	9.1%	13.6%	0.0%	9.1%	4.5%	4.5%
50*th*	4.0%	12.0%	4.0%	20.0%	12.0%	24.0%	20.0%	4.0%	0.0%	0.0%
60*th*	4.0%	4.0%	16.0%	12.0%	16.0%	0.0%	20.0%	16.0%	8.0%	4.0%
70*th*	13.0%	0.0%	4.3%	17.4%	8.7%	21.7%	0.0%	21.7%	13.0%	0.0%
80*th*	7.7%	7.7%	7.7%	3.8%	19.2%	3.8%	26.9%	7.7%	15.4%	0.0%
90*th*	0.0%	8.3%	8.3%	0.0%	8.3%	4.2%	25.0%	16.7%	25.0%	4.2%
100*th*	4.2%	0.0%	0.0%	4.2%	4.2%	4.2%	12.5%	8.3%	8.3%	54.2%

(k) Korea: Electrical Machinery 1985-1995

1985 \ 1995	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	12.5%	25.0%	12.5%	25.0%	12.5%	0.0%	12.5%	0.0%	0.0%	0.0%
20*th*	0.0%	16.7%	16.7%	0.0%	50.0%	16.7%	0.0%	0.0%	0.0%	0.0%
30*th*	0.0%	14.3%	28.6%	14.3%	0.0%	28.6%	0.0%	14.3%	0.0%	0.0%
40*th*	14.3%	0.0%	0.0%	0.0%	28.6%	42.9%	14.3%	0.0%	0.0%	0.0%
50*th*	0.0%	14.3%	0.0%	14.3%	14.3%	0.0%	14.3%	42.9%	0.0%	0.0%
60*th*	0.0%	0.0%	14.3%	0.0%	0.0%	42.9%	0.0%	28.6%	0.0%	14.3%
70*th*	0.0%	0.0%	14.3%	14.3%	0.0%	14.3%	14.3%	28.6%	14.3%	0.0%
80*th*	0.0%	0.0%	28.6%	28.6%	14.3%	28.6%	0.0%	0.0%	0.0%	0.0%
90*th*	0.0%	0.0%	14.3%	14.3%	0.0%	0.0%	14.3%	42.9%	14.3%	0.0%
100*th*	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	33.3%	33.3%

(l) Korea: Electrical Machinery 1995-1999

1995 \ 1999	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	0.0%	22.2%	27.8%	11.1%	5.6%	11.1%	5.6%	5.6%	5.6%	5.6%
20*th*	5.0%	15.0%	15.0%	10.0%	10.0%	20.0%	15.0%	5.0%	0.0%	5.0%
30*th*	21.1%	5.3%	15.8%	5.3%	10.5%	15.8%	10.5%	5.3%	5.3%	5.3%
40*th*	5.0%	10.0%	15.0%	10.0%	15.0%	5.0%	25.0%	10.0%	5.0%	0.0%
50*th*	5.0%	10.0%	5.0%	25.0%	5.0%	10.0%	20.0%	10.0%	5.0%	5.0%
60*th*	20.0%	10.0%	5.0%	10.0%	15.0%	20.0%	5.0%	5.0%	10.0%	0.0%
70*th*	5.3%	5.3%	15.8%	15.8%	10.5%	15.8%	10.5%	5.3%	5.3%	10.5%
80*th*	5.3%	0.0%	10.5%	5.3%	15.8%	15.8%	15.8%	0.0%	15.8%	15.8%
90*th*	14.3%	0.0%	9.5%	14.3%	14.3%	4.8%	9.5%	19.0%	9.5%	4.8%
100*th*	5.6%	11.1%	0.0%	11.1%	16.7%	5.6%	0.0%	5.6%	11.1%	33.3%

(Table 6 Continued)

(m) Korea: Electrical Machinery 1999-2004

	2004									
1999	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	16.0%	4.0%	12.0%	12.0%	4.0%	0.0%	8.0%	4.0%	16.0%	24.0%
20*th*	7.1%	25.0%	10.7%	14.3%	17.9%	7.1%	3.6%	3.6%	3.6%	7.1%
30*th*	13.3%	3.3%	10.0%	13.3%	23.3%	6.7%	10.0%	6.7%	6.7%	6.7%
40*th*	11.5%	3.8%	15.4%	19.2%	15.4%	7.7%	7.7%	15.4%	3.8%	0.0%
50*th*	16.7%	10.0%	16.7%	3.3%	16.7%	3.3%	16.7%	6.7%	6.7%	3.3%
60*th*	3.4%	10.3%	6.9%	6.9%	0.0%	24.1%	20.7%	10.3%	10.3%	6.9%
70*th*	9.1%	21.2%	12.1%	3.0%	12.1%	6.1%	15.2%	9.1%	9.1%	3.0%
80*th*	8.0%	8.0%	4.0%	12.0%	12.0%	20.0%	8.0%	8.0%	8.0%	12.0%
90*th*	6.5%	6.5%	9.7%	9.7%	6.5%	6.5%	9.7%	19.4%	6.5%	19.4%
100*th*	20.0%	16.7%	13.3%	6.7%	6.7%	3.3%	0.0%	10.0%	16.7%	6.7%

(n) China: Electrical Machinery 1999-2004

	2004									
1999	10*th*	20*th*	30*th*	40*th*	50*th*	60*th*	70*th*	80*th*	90*th*	100*th*
10*th*	16.7%	33.3%	16.7%	0.0%	0.0%	0.0%	16.7%	0.0%	16.7%	0.0%
20*th*	50.0%	25.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%
30*th*	0.0%	33.3%	0.0%	16.7%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40*th*	12.5%	12.5%	0.0%	25.0%	25.0%	0.0%	12.5%	0.0%	12.5%	0.0%
50*th*	12.5%	25.0%	0.0%	25.0%	0.0%	25.0%	0.0%	12.5%	0.0%	0.0%
60*th*	0.0%	0.0%	22.2%	0.0%	11.1%	11.1%	0.0%	22.2%	11.1%	22.2%
70*th*	20.0%	0.0%	0.0%	20.0%	0.0%	20.0%	20.0%	0.0%	0.0%	20.0%
80*th*	25.0%	0.0%	12.5%	0.0%	0.0%	0.0%	37.5%	0.0%	0.0%	25.0%
90*th*	0.0%	0.0%	16.7%	0.0%	0.0%	0.0%	33.3%	0.0%	33.3%	16.7%
100*th*	0.0%	0.0%	14.3%	14.3%	0.0%	14.3%	0.0%	14.3%	14.3%	28.6%

industry, approximately 30% of firms in the first decile (the lowest 10% group) as of the beginning of each period stayed in the first decile as of the end of each period. Moreover, 40-65% of firms in the 10th decile as of the beginning of each period stayed in the 10^{th} decile (the highest 10% group) as of the end of each period. On the other hand, in the cases of the Korean and the Chinese chemical industries, the share of firms staying in the first decile during each period was around 14-23%, while the share of firms staying in the 10^{th} decile was around 23-33%. Thus, compared with the cases of Korea and China, higher-TFP firms in the Japanese chemical industry were more likely to stay in the higher-TFP group and lower-TFP firms were more likely to stay in the lower-TFP group.

In the case of the Japanese electrical machinery industry, 55.6% (54.2%) of firms in the first decile (the 10^{th} decile) as of 1999 stayed in the first decile (the 10^{th} decile) as of 2004. Comparing A_{8595J} with A_{9599J} and A_{9904J}, ranking changes become less frequent over time. Contrary to the Japanese case, only 16.0% (6.7%) of firms in the first decile (the 10^{th} decile) as of 1999 stayed in the first decile (the 10^{th} decile) as of 2004 in the case of Korea. As for China, 16.7% (28.6%) of firms in the first decile (the 10^{th} decile) as of 1999 stayed in the first decile (the 10^{th} decile) as of 2004. It follows that the TFP ranking changed relatively frequently in the case of the Korean electrical machinery industry.

IV. Productivity Convergence toward Frontier Firms

Our empirical analysis so far has shown that some industries in Korea achieved rapid TFP growth and that the ranking of firm TFP fluctuates more for Korean and Chinese firms than Japanese firms. On the other hand, industry-level TFP growth rates were very low and changes in firm TFP ranking very infrequent in Japanese industries. As a result, TFP levels in Korea have even surpassed Japanese TFP levels in some industries, such as stone, clay, and glass products, non-electrical machinery, electrical machinery, and transportation. Moreover, the dispersion of firm TFP has been widening in more industries in Japan than in Korea, although the magnitude of the TFP dispersion is much smaller for Japanese industries. These observations imply that technology diffusion across firms appear to be stronger in Korea than in Japan and that convergence to the national frontier firms is more rapid for Korean firms than for Japanese firms.

In this section, following the methodology employed by Bartelsman, Haskel, and Martin (2006), we estimate the speed of convergence to the productivity frontier. Like Bartelsman, Haskel, and Martin (2006), we assume that changes in the knowledge capital of firm f, ΔA_f, originate from changes in the knowledge stock within the firm itself and from outside the firm, because knowledge inputs are potentially transferable and non-rival within and across firms. Therefore, we may write:

$$\Delta A_f = f(X_f,\ A_f,\ A_{\_f}) \tag{4}$$

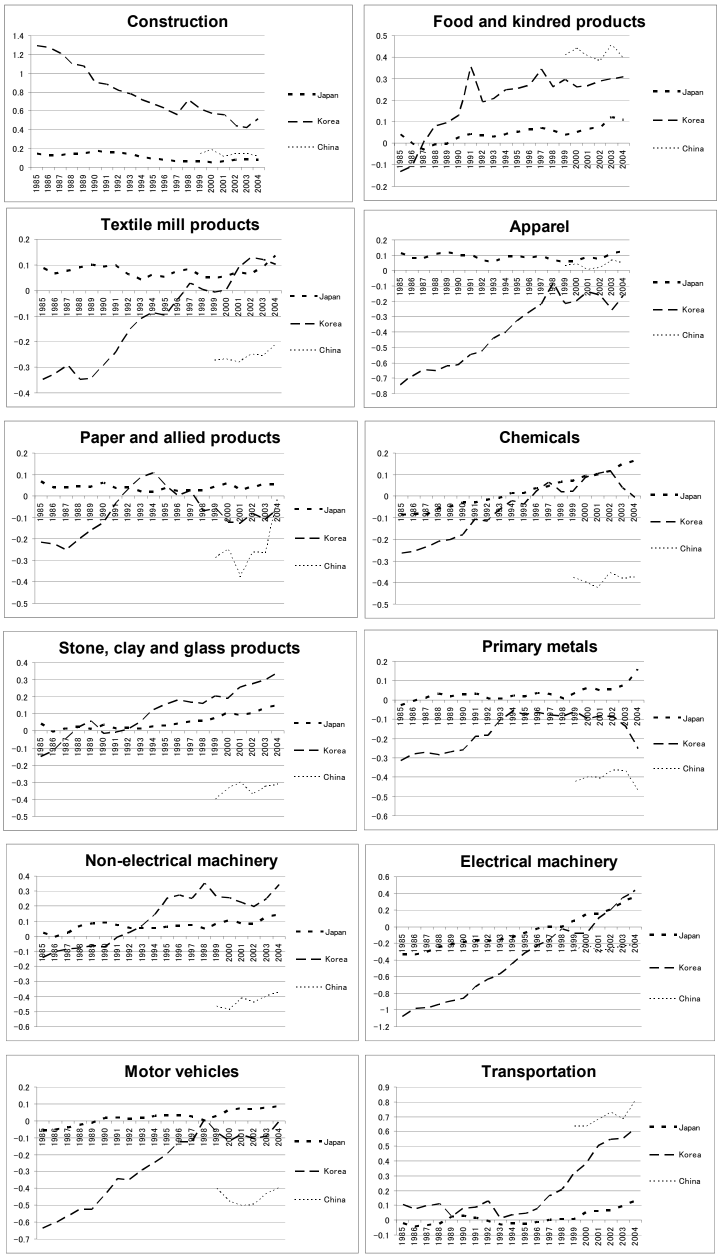

FIGURE 3

TRENDS IN TFP OF NATIONAL FRONTIER FIRMS where X_f are the physical inputs into the idea process. Log linearizing this yields:

$$\Delta \ln A_f = \alpha_1 \ln X_f + (\alpha_2 - \alpha_3) \ln A_f + \alpha_3 \ln\left(\frac{A_{\_f}}{A_f}\right) \tag{5}$$

where it is usual to impose $\alpha_2 = \alpha_3$, so the overall growth of A only depends on the relative levels of $A_{\_f}$ and A_f. As in Bartelsman, Haskel, and Martin (2006) and other studies in the convergence literature, we identify $A_{\_f}$ as the productivity level of the leading firm. In order to avoid measurement error problems, we take the average of the TFP of firms within the top-quartile of the TFP distribution by industry, year, and country. We call the productivity levels of the top-quartile firms the national frontier, A_N. The term $\ln(A_N/A_f)$ indicates the productivity gap between the national frontier and firm f. Therefore, we define the distance to the national frontier (DTF_N) as follows:

$$\begin{aligned} &DTF_{Nft} = \ln A_N - \ln A_f \quad \text{if } \ln A_f < \ln A_N \\ &DTF_{Nft} = 0, \text{ otherwise} \end{aligned} \tag{6}$$

Using firm-level TFP as a proxy for firms' knowledge capital, we can estimate the version of (5) given by:

$$\Delta \ln TFP_{ft} = \alpha + \beta DTF_{Nf,t-1} + \mu_f + \varepsilon_{ft} \tag{7}$$

where α represents a constant as well as a dummy variable for time. β measures the pull from the frontier. If the marginal effect of technology spillovers or diffusion is larger for firms with a low TFP level,[15] the value of β will be positive and we will see a catching-up of low-productivity firms to the national frontier. The firm-specific fixed effect, μ_f, captures the effect of firm actions and firm and industry characteristics on firm-level productivity growth. Although it would be desirable to include a better proxy for investment in knowledge creation such as R&D intensity, we do not do so

[15] Whether low-productivity firms can benefit from the "advantages of backwardness" depends on patterns of consumption and on the existence of a threshold level of infrastructural development (Dowrick and Gemmell 1991; Hall and Jones 1999; Barro and Sala-i-Martin 2004).

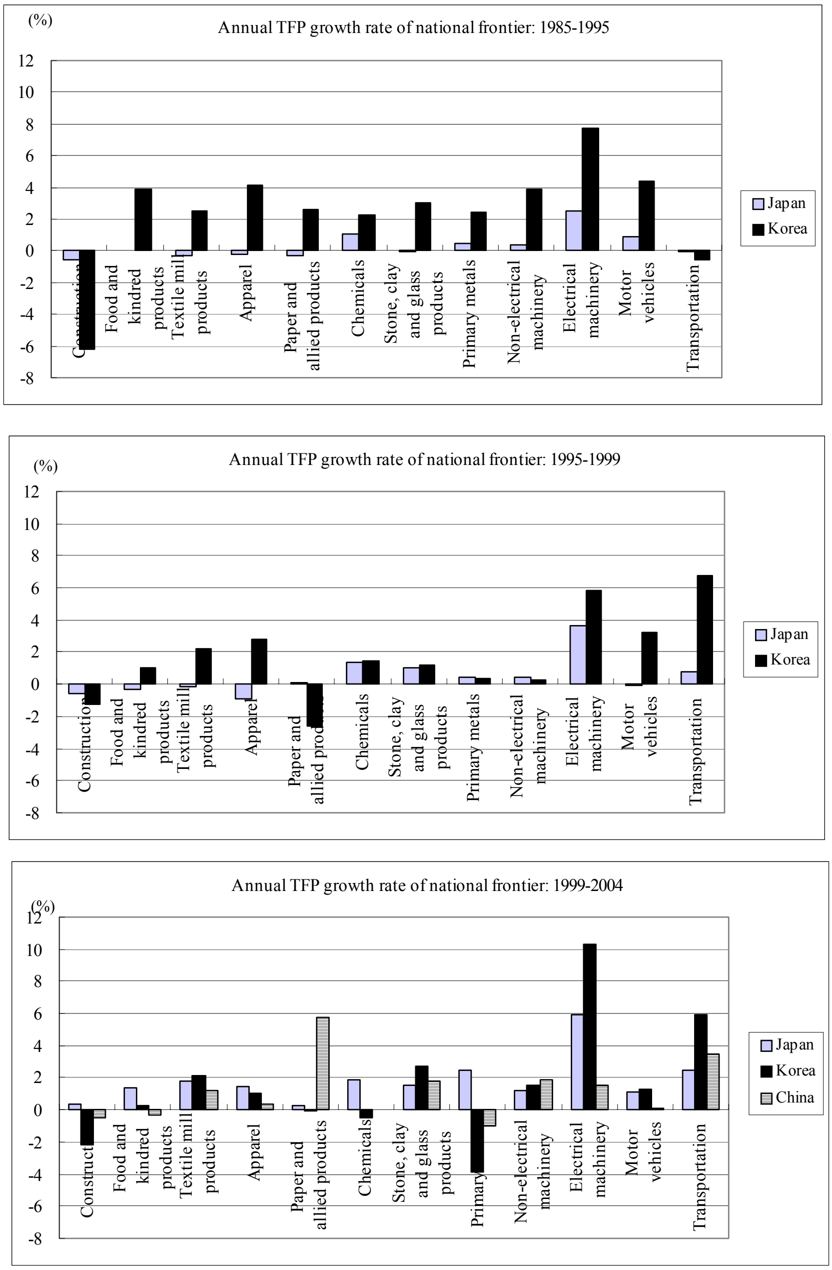

FIGURE 4

ANNUAL TFP GROWTH RATE FOR NATIONAL FRONTIER FIRMS because such data are not available for Korean and Chinese firms. In addition, we include the growth potential of the industry to control for industry characteristics. The growth potential is measured as the lagged average growth rate of the Japanese national frontier and the Korean national frontier.[16] We estimate Equation (7) using the fixed-effect panel regression method.

Before moving on to the estimation results, let us have a look at the trends in the national frontier TFP levels for the 12 major industries (Figure 3). Consistent with our analysis in the previous sections, the Japanese national frontier is the highest in the majority of industries. As Bartelsman, Haskel, and Martin (2006) explain, firms with a knowledge gap *vis-à-vis* the national frontier firms can potentially learn from them while the national frontier firms presumably can also learn from the global frontier firms. Given the close economic relationships between Japan, Korea, and China, Korean and Chinese firms may have learned from Japanese frontier firms. Therefore, for Korean and Chinese firms, we also estimate the speed of convergence to the Japanese national frontier in the ten industries where the Japanese frontier is consistently higher than the Korean and Chinese frontiers, that is, textile mill products, apparel, paper and allied products, chemicals, primary metal products, electrical machinery, motor vehicles, rubber and miscellaneous plastics, miscellaneous manufacturing products, and trade.

The estimation results are shown in Table 7. Column 1 shows a standard regression of TFP growth on the distance from the national frontier, using as control variables both the lagged growth rate of the industry TFP (the average growth rate of the Japanese and the Korean national frontiers, $dAF_{JK}(t-1)$) and year dummy variables. The marginal pull from the national frontier is 0.51.[17] In order to examine whether the pull from the national frontier is different among countries, we interact the DTF_N measure with a dummy for each country (*JP, KR, CH*) separately. The result is

[16] In some specifications, we use the lagged growth rate of the Japanese national frontier as a proxy for the growth potential of the industry.

[17] The marginal pull from the national frontier estimated by Bartelsman, Haskel, and Martin (2006) is around 0.2-0.3 for U.K. firms, although our results cannot be directly compared with theirs because of the different specification. Moreover, they use labor productivity as a productivity measure.

TABLE 7
FIXED EFFECT PANEL REGRESSION RESULTS

	(1) All	(2) All	(3) JPN & KOR	(4) JPN & KOR	(5) KOR & CHN	(6) KOR	(7) CHN
DTF_N	0.5132		0.4753			0.4527	0.1629
	(122.78) ***		(114.68) ***			(31.78) ***	(2.34) **
DTF_N*JP		0.4092		0.4088			
		(58.85) ***		(62.36) ***			
DTF_N*KR		0.5181		0.5180	0.4466		
		(92.60) ***		(98.20) ***	(30.43) ***		
DTF_N*CH		0.8322			0.1413		
		(65.51) ***			(2.67) ***		
DTF_J						0.0783	0.8310
						(6.73) ***	(11.56) ***
DTF_J*KR					0.0855		
					(7.15) ***		
DTF_J*CH					0.8660		
					(15.98) ***		
$dAF_{JK}(t-1)$	0.0029	0.0083	0.0043	0.0080			
	(0.29)	(0.83)	(0.45)	(0.83)			
$dAF_J(t-1)$					0.0359	-0.0065	0.2204
					(0.52)	(-0.09)	(0.78)
No. of obs.	66423	66423	63757	63757	12220	10825	1395
No. of groups	6407	6407	5481	5481	1448	962	486
F statistics	828.7 ***	801.3 ***	731.6 ***	705.6 ***	180.0 ***	161.8 ***	97.3 ***

Notes: 1) Dependent variable: TFP growth rate
2) *t*-test for the difference in estimated coefficients for Equation (2)
H_0: DTF_N*JP *vs.* DTF_N*KR; significant at 1 percent level
H_0: DTF_N*KR *vs.* DTF_N*CH; significant at 1 percent level
3) All regressions include year dummies. *DTF* terms are all lagged one period.
4) *t*-values are in parentheses.
5) Significance at the 1, 5, and 10 percent level is indicated by ***, **, and *, respectively.

shown in column 2 and indicates that the marginal impact of the national frontier is largest for Chinese firms, followed by that for Korean and then Japanese firms (the differences among these marginal effects are statistically significant).[18] This result suggests that the convergence speed to the national frontier is the weakest

[18] In order to check the robustness of this result, we estimated the same equations only for Japanese and Korean firms, because data on Chinese firms are available only from 1999. The results were very similar and robust.

for Japanese firms. Looking at the convergence speed to the Japanese frontier for Korean and Chinese firms (columns 5-7), we find that the marginal impact of the Japanese frontier on Korean TFP growth is much smaller than that of the Korean national frontier (0.08 and 0.45 respectively).[19] However, in the case of Chinese firms, the marginal impact of the Japanese frontier is much larger than that of the Chinese national frontier. Although this may reflect the fact that the TFP growth of Chinese national frontier firms has stagnated in many industries (Figure 3), it may be possible that the knowledge spillovers among Korean firms are stronger than those among firms in China, where foreign-owned firms are playing a crucial role in technological upgrading.

Table 8 goes on to explore how much the distance-to-the-frontier (DTF) effects vary with the distance to the frontier. We assign quartile dummies for DTF measures (by country, year, and industry) and multiply them with each dummy separately, thus allowing the marginal effect of the different distances to vary according to quartile-location of distance. In columns 1-3, we show the results when only the distance to the national frontier is included. In the case of Korea, the DTF_N effect increases with the distance to the national frontier. On the other hand, the DTF_N effect is more or less flat for Japan and China, except for a slight increase for firms in the quartile farthest from the frontier. In columns 4 and 5, we report the result of adding the four Japanese frontier terms for the ten industries previously mentioned where the Japanese national frontier is consistently higher than that of Korea and China (see Figure 3 above). First, all the DTF_J coefficients are lower than the DTF_N coefficients in the case of Korea, while the Chinese results are exactly the opposite. Second, in the case of Korea, the DTF_J coefficients are declining with the distance to the Japanese frontier while the DTF_N coefficients are still increasing with the distance to the national frontier. In the case of China, although the DTF_J coefficients are somewhat decreasing with the distance, the difference between the coefficients for the top quartile and the bottom quartile is not statistically significant.

In sum, all these results point to the following interpretation.

[19] The estimations reported in columns 5-7 include the lagged growth rate of the Japanese national frontier, $dAF_J(t-1)$, to control for the industry's growth potential.

TABLE 8

FIXED EFFECT PANEL REGRESSION RESULTS: INCLUDING INTERACTION-TERMS

	(1) Japan	(2) Korea	(3) China	(4) Korea	(5) China
$DTF_N{*}q1$	0.3967	0.5358	0.8341	0.5074	0.2301
	(86.21) ***	(65.47) ***	(29.70) ***	(24.23) ***	(3.15) ***
$DTF_N{*}q2$	0.3757	0.4356	0.7823	0.3970	0.0547
	(59.29) ***	(31.18) ***	(14.82) ***	(13.72) ***	(0.43)
$DTF_N{*}q3$	0.3723	0.4091	0.7952	0.4268	0.1304
	(41.83) ***	(19.45) ***	(10.35) ***	(11.54) ***	(0.77)
$DTF_N{*}q4$	0.3801	0.3722	0.8244	0.3608	-0.4345
	(20.70) ***	(7.65) ***	(4.64) ***	(5.69) ***	(-1.45)
$DTF_J{*}q1$				0.0424	0.8212
				(2.60) ***	(11.29) ***
$DTF_J{*}q2$				0.0908	0.9079
				(6.02) ***	(10.70) ***
$DTF_J{*}q3$				0.0939	0.8883
				(6.20) ***	(9.99) ***
$DTF_J{*}q4$				0.0998	0.9810
				(6.13) ***	(10.00) ***
$dAF_{JK}(t-1)$	-0.0209	0.0673	0.0335	0.0879	0.5045
	(-2.73) ***	(2.41) ***	(0.25)	(1.29)	(2.30) **
No. of obs.	45624	18133	2666	10825	1395
No. of groups	3803	1678	926	962	486
F statistics	473.0 ***	225.9 ***	114.3 ***	125.6 ***	50.6 ***
t-test for the difference in estimated coefficients					
H_0: $DTF_N{*}q1$ *vs.* $DTF_N{*}q4$					
	not significant	significant ***	not significant	significant **	significant **
H_0: $DTF_J{*}q1$ *vs.* $DTF_J{*}q4$					
	n.a.	n.a.	n.a.	significant **	not significant

Notes: 1) Dependent variable: TFP growth rate
2) $q1$: the lowest 25%
$q2$: above 25% and below 50%
$q3$: above 50% and below 75%
$q4$: the highest 25%
3) n.a. = not applicable.
4) All regressions include year dummies. *DTF* terms are all lagged one period.
5) t-values are in parentheses.
6) Significance at the 1, 5, and 10 percent level is indicated by ***, **, and *, respectively.

First, in the case of Japan, the pull from the national frontier is the weakest among the three countries, but the pull from the national frontier does not fall nor increase with technological distance. Second, in the case of Korea, the national frontier exerts a stronger pull on domestic firms than the Japanese frontier. Although the convergence rate is low for firms that are distant from the Japanese frontier, the convergence rate is higher for firms that are distant from the national frontier. These results suggest that low-performing firms are rapidly catching up to the national frontier, while national frontier firms are also catching up to leading Japanese firms, though at a lower speed. Third, in the case of China, the pull from the national frontier is weaker than the pull from the Japanese frontier.

Thus, the strongest convergence towards the national frontier is found for Korean firms. This, in turn, suggests that if Korean national frontier firms were to reach the global frontier, we would expect that all Korean firms to catch up to the global frontier sooner or later. Therefore, the TFP growth of Korean national frontier firms is critical to Korea's productivity improvement and catch-up process. Figure 4 shows the annual TFP growth rate of national frontier firms in the three countries. Although in many industries the Korean TFP frontier had been advancing much more rapidly than the Japanese frontier up until 1999, Japanese frontier growth in many industries then outpaced Korea's from 1999 to 2004. While the Korean electrical machinery industry continues to raise its TFP at a high speed, TFP growth in many other industries has been stagnant in recent years. These figures suggest that the Korean electrical machinery industry will catch up to the global frontier in the near future, while other industries are far from achieving this result.

In Japan, the TFP growth rate of the national frontier is low for many industries, although it has been improving in recent years. The low growth rate of the national frontier and the weak pull from the national frontier may result in a further widening of the dispersion of productivity within an industry as well as the stagnation of industry-level productivity.

V. Concluding Remarks and Implications for Future Research

Using firm-level data, this paper explored differences in productivity growth and dispersion among Japanese, Korean, and Chinese listed firms. Moreover, we investigated the productivity convergence pattern for these countries.

We found the following. First, TFP has been growing faster in Korea than in Japan in some industries, such as textile mill products, apparel, stone, clay and glass products, non-electrical machinery, electrical machinery, motor vehicles, and transportation. In several industries, such as stone, clay and glass products, non-electrical machinery, electrical machinery, and transportation, the Korean TFP level even surpasses the Japanese TFP level.

Second, in most industries, the within-industry dispersion of productivity is smallest in Japan. Moreover, Japan has experienced a widening dispersion in more industries than Korea, although in some industries, the speed of the widening of the dispersion is faster in Korea than in Japan.

Third, in Japan, TFP rankings within an industry are quite stable in many industries, while the rankings change frequently in Korea.

Fourth, the convergence analysis revealed that the pull from the national frontier was weaker in the case of Japan than that of Korea. In the case of Korea, lower-performing firms have been catching up to the national frontier at a faster speed than higher-performing firms, which provides evidence of strong convergence toward the national frontier. Moreover, the rapid TFP growth of the Korean national frontier in the electrical machinery industry suggests that this industry will catch up with the global frontier in the near future, while convergence toward the global frontier does not appear to be very strong in other industries.

According to our findings, the TFP distribution is very stable over time in Japan, which is conspicuously different from the situation in Korea and China. Moreover, the speed of TFP convergence is the slowest in Japan. These differences may be attributable to differences in country- or industry-level technological capabilities, industry organization, market conditions, and institutional infrastructure, or in micro-level R&D activities and managerial ability.[20] Although we

[20] Previous studies on within-country convergence show that the

did not analyze in detail the effect of these macro- and micro-level characteristics due to a lack of data, particularly for Korean and Chinese firms, this is an issue to be further scrutinized if the necessary data become available. Furthermore, firm-level or industry-level analyses including a greater number of both developed and developing countries should provide us with an understanding of the relationship between productivity dynamics and country-specific factors.

Moreover, our finding of a positive catching-up effect towards the national frontier in all three countries may seem contradictory to another of our findings, namely that within-industry TFP dispersion has been widening in many industries. A possible explanation is that our convergence analysis only takes account of "passive" technology diffusion or, in other words, "autonomous" productivity convergence (Nishimura, Nakajima, and Kiyota 2005). Although we partly controlled for firm-specific characteristics using the fixed-effect panel estimation methodology, we did not fully take account of "active" technology diffusion which is brought about by firms' R&D activities for the purpose of adopting new technology. In addition, as many recent micro-level studies show, exposure to international competition possibly affects firms' productivity.[21] We would like to further scrutinize the issue related to firm-level convergence and within-industry dispersion of productivity in the future. Unfortunately, we were unable to do so in this study due to the unavailability of firm-level data on the R&D and international activities of Korean and Chinese firms.

The mechanism of productivity convergence to frontier firms within a country and across countries is an issue that deserves further attention and more rigorous empirical analysis. Although the compilation of international micro data for East Asian countries is not an easy task, the development of internationally comparable measures based on micro data could shed more light on the growth mechanisms underlying the so-called "East Asian economic miracle," as well as the determinants and consequence of the heterogeneity of firms.

convergence speed is influenced by firms' own R&D activities (Nishimura, Nakajima, and Kiyota 2005) and the presence of foreign-owned firms (Griffith, Redding, and Simpson 2002).

[21] See Fukao and Kwon (2006) for the case of Japan. Also refer to Bartelsman and Doms (2000) for a comprehensive survey.

Moreover, we need to improve the quality and coverage of our micro data as well as currency conversion factors, human capital, price deflators, *etc*., in order to measure industry- or firm-level productivity more accurately. It is also important to further develop the methodology used for the measurement of internationally-comparable TFP. In this study, we were not able to analyze the productivity of global frontier firms because comprehensive firm-level data were not available for the United States and for European countries. A comparison of the performance and/or competition between Asian frontier firms and frontier firms in developed countries from other regions would be another interesting research topic which deserves further investigation.

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Appendix

APPENDIX TABLE 1

TFP GROWTH RATES AND THE GAP BETWEEN THE WEIGHTED AVERAGE AND THE UNWEIGHTED AVERAGE TFP LEVELS

Manufacturing Industry			TFP growth rate			Difference in the gap*		
			Japan	Korea	China	Japan	Korea	China
6	Food and kindred products	1985-1995	-0.4%	37.8%	n.a.	0.000	0.024	n.a.
		1995-1999	-0.9%	-5.6%	n.a.	0.007	0.001	n.a.
		1999-2004	6.0%	9.5%	-1.5%	0.006	0.044	0.071
7	Textile mill products	1985-1995	-6.0%	30.4%	n.a.	0.010	0.032	n.a.
		1995-1999	-0.2%	7.9%	n.a.	-0.002	0.016	n.a.
		1999-2004	7.8%	8.2%	0.8%	-0.004	0.027	0.016
8	Apparel	1985-1995	-5.7%	42.2%	n.a.	-0.003	0.000	n.a.
		1995-1999	-2.5%	1.5%	n.a.	-0.013	-0.005	n.a.
		1999-2004	5.0%	13.2%	4.0%	-0.011	0.013	-0.120
9	Lumber and wood	1985-1995	-5.6%	-1.5%	n.a.	-0.026	-0.051	n.a.
		1995-1999	-4.0%	4.1%	n.a.	-0.007	0.038	n.a.
		1999-2004	1.3%	15.7%	n.a.	0.011	0.022	n.a.
10	Furniture and fixtures	1985-1995	-6.3%	30.5%	n.a.	-0.009	0.027	n.a.
		1995-1999	-1.9%	5.4%	n.a.	0.003	0.012	n.a.
		1999-2004	2.5%	-1.0%	-5.8%	0.000	-0.015	0.136
11	Paper and allied products	1985-1995	-2.2%	21.6%	n.a.	-0.011	-0.053	n.a.
		1995-1999	-1.7%	-15.6%	n.a.	-0.010	-0.023	n.a.
		1999-2004	2.9%	7.9%	7.3%	0.006	0.035	0.058

(Appendix Table 1 Continued)

Manufacturing Industry			TFP growth rate			Difference in the gap*		
			Japan	Korea	China	Japan	Korea	China
12	Printing, publishing and allied products	1985-1995	-5.9%	69.9%	n.a.	-0.006	0.082	n.a.
		1995-1999	-4.8%	-3.0%	n.a.	-0.008	-0.085	n.a.
		1999-2004	0.3%	-11.1%	-2.9%	-0.035	0.127	0.150
13	Chemicals	1985-1995	8.1%	24.4%	n.a.	0.004	0.008	n.a.
		1995-1999	6.3%	7.9%	n.a.	0.010	0.010	n.a.
		1999-2004	9.7%	-4.8%	3.0%	0.030	0.001	0.010
14	Petroleum and coal products	1985-1995	-34.6%	84.6%	n.a.	-0.005	-0.009	n.a.
		1995-1999	0.3%	-55.7%	n.a.	0.008	-0.048	n.a.
		1999-2004	10.5%	-24.4%	12.7%	0.039	0.080	0.068
15	Leather	1985-1995	-19.3%	8.7%	n.a.	0.023	0.062	n.a.
		1995-1999	-1.4%	-6.5%	n.a.	-0.013	0.036	n.a.
		1999-2004	8.0%	-6.5%	0.0%	-0.003	-0.003	0.045
16	Stone, clay and glass products	1985-1995	-2.0%	30.3%	n.a.	-0.013	-0.050	n.a.
		1995-1999	3.0%	1.1%	n.a.	0.010	0.006	n.a.
		1999-2004	10.4%	17.4%	18.5%	0.032	0.041	0.062
17	Primary metals	1985-1995	7.0%	27.8%	n.a.	0.033	0.016	n.a.
		1995-1999	2.7%	-4.3%	n.a.	0.015	-0.022	n.a.
		1999-2004	7.7%	-14.3%	-1.4%	0.006	0.031	0.039
18	Fabricated metals	1985-1995	-2.1%	57.4%	n.a.	-0.029	0.140	n.a.
		1995-1999	0.3%	-12.0%	n.a.	0.000	0.003	n.a.
		1999-2004	3.1%	-7.5%	12.6%	0.015	0.010	0.271
19	Non-electrical machinery	1985-1995	6.8%	37.5%	n.a.	0.030	0.021	n.a.
		1995-1999	-0.6%	-3.7%	n.a.	-0.008	-0.036	n.a.
		1999-2004	8.9%	8.3%	13.5%	0.007	0.060	-0.051
20	Electrical machinery	1985-1995	26.7%	92.3%	n.a.	0.014	0.195	n.a.
		1995-1999	12.7%	2.9%	n.a.	-0.003	-0.187	n.a.
		1999-2004	25.9%	55.2%	14.1%	-0.010	0.058	-0.062
21	Motor vehicles	1985-1995	7.4%	48.4%	n.a.	-0.018	-0.005	n.a.
		1995-1999	1.1%	4.1%	n.a.	0.020	-0.059	n.a.
		1999-2004	5.6%	7.0%	13.9%	0.002	-0.027	0.102
22	Transportation equipment and ordnance	1985-1995	10.7%	35.9%	n.a.	0.017	-0.006	n.a.
		1995-1999	-3.1%	6.6%	n.a.	-0.001	0.034	n.a.
		1999-2004	6.5%	-13.4%	17.8%	0.008	-0.035	-0.115
23	Instruments	1985-1995	5.7%	36.9%	n.a.	0.017	0.040	n.a.
		1995-1999	0.9%	7.8%	n.a.	-0.010	0.007	n.a.
		1999-2004	7.1%	-3.5%	13.0%	-0.010	0.021	0.092
24	Rubber and misc. plastics	1985-1995	5.0%	22.0%	n.a.	0.007	-0.001	n.a.
		1995-1999	0.8%	5.8%	n.a.	0.005	0.024	n.a.
		1999-2004	4.3%	10.7%	7.1%	-0.001	0.096	0.042
25	Misc. manufacturing	1985-1995	8.2%	28.9%	n.a.	0.055	0.053	n.a.
		1995-1999	9.1%	7.0%	n.a.	-0.015	-0.081	n.a.
		1999-2004	18.7%	6.9%	-2.4%	0.031	0.020	0.095

(Appendix Table 1 Continued)

Non-Manufacturing Industry			TFP growth rate			Difference in the gap*		
			Japan	Korea	China	Japan	Korea	China
1	Agriculture	1985-1995	-11.1%	-58.7%	n.a.	-0.001	0.003	n.a.
		1995-1999	8.2%	-1.0%	n.a.	-0.004	-0.059	n.a.
		1999-2004	6.0%	-19.6%	-11.6%	0.009	0.021	0.149
2	Coal mining	1985-1995	-13.1%	-55.5%	n.a.	0.005	0.000	n.a.
		1995-1999	10.0%	6.6%	n.a.	-0.006	0.000	n.a.
		1999-2004	16.9%	46.8%	-34.1%	-0.003	0.000	-0.077
3	Metal and nonmetallic mining	1985-1995	-8.6%	n.a.	n.a.	0.002	n.a.	n.a.
		1995-1999	14.0%	n.a.	n.a.	0.018	n.a.	n.a.
		1999-2004	9.8%	n.a.	-8.6%	-0.036	n.a.	0.228
4	Oil and gas extraction	1985-1995	-45.3%	n.a.	n.a.	-0.117	n.a.	n.a.
		1995-1999	16.6%	n.a.	n.a.	-0.048	n.a.	n.a.
		1999-2004	40.3%	n.a.	-84.5%	0.075	n.a.	-0.484
5	Construction	1985-1995	-5.7%	-48.8%	n.a.	-0.019	0.077	n.a.
		1995-1999	-1.2%	-3.1%	n.a.	0.004	0.058	n.a.
		1999-2004	0.9%	-5.3%	-8.7%	0.015	-0.016	-0.091
26	Transportation	1985-1995	-1.3%	-3.7%	n.a.	-0.006	-0.058	n.a.
		1995-1999	3.3%	10.5%	n.a.	0.021	-0.141	n.a.
		1999-2004	9.0%	45.8%	24.7%	0.019	0.091	0.178
27	Communication	1985-1995	6.6%	125.1%	n.a.	-0.045	1.185	n.a.
		1995-1999	38.9%	41.5%	n.a.	0.117	0.242	n.a.
		1999-2004	-2.6%	63.9%	24.4%	-0.100	-0.009	0.070
28	Electrical utilities	1985-1995	-11.0%	93.6%	n.a.	-0.015	0.000	n.a.
		1995-1999	6.7%	-21.1%	n.a.	0.014	0.000	n.a.
		1999-2004	9.6%	-1.8%	2.3%	-0.025	0.000	0.044
29	Gas utilities	1985-1995	-23.3%	77.0%	n.a.	0.001	-0.618	n.a.
		1995-1999	-1.5%	-12.5%	n.a.	-0.006	-0.102	n.a.
		1999-2004	12.7%	8.5%	10.0%	-0.002	0.062	0.074
30	Trade	1985-1995	7.5%	22.0%	n.a.	-0.085	0.013	n.a.
		1995-1999	2.4%	10.9%	n.a.	-0.053	-0.081	n.a.
		1999-2004	14.1%	7.8%	9.5%	0.025	0.097	0.164
31	Finance, insurance and real estate	1985-1995	-13.1%	n.a.	n.a.	-0.056	n.a.	n.a.
		1995-1999	-0.7%	n.a.	n.a.	0.007	n.a.	n.a.
		1999-2004	1.1%	n.a.	14.2%	-0.011	n.a.	0.053
32	Other private services	1985-1995	-1.9%	-45.9%	n.a.	-0.004	0.023	n.a.
		1995-1999	8.8%	-0.4%	n.a.	0.017	-0.040	n.a.
		1999-2004	6.1%	3.9%	-1.6%	-0.015	0.115	-0.008
33	Public service	1985-1995	-24.6%	n.a.	n.a.	0.000	n.a.	n.a.
		1995-1999	-7.4%	n.a.	n.a.	0.000	n.a.	n.a.
		1999-2004	4.8%	n.a.	n.a.	0.000	n.a.	n.a.

Note: * Difference between the starting year and the ending year during each period.

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Comments and Discussion

*Comments by Wooseok Ok**

This paper investigates the patterns and reasons of productivity growth in the three North-East Asian Countries, using firm-level data. While studies based on micro-level data are getting more and more popular in the productivity analysis in recent economic literature due to the potential of this type of data, their full exploitation is often hampered by data limitations, especially by the facts that firm- or establishment-level data are often restricted to a national countries and that it is often very hard to have a harmonized dataset which allows an international comparison. This paper tackles straight forwardly this kind of difficulty, by constructing a dataset which harmonize the firm-level data existing in the three Northeast Asian countries, and effectuating very meaningful analyses based on this dataset.

The only regret of this paper is that the findings, which are very insightful and interesting, are not backed up sufficiently by theoretical arguments so that it does not reveal its full implication on the very debate regarding with the economic growth of the three Northeast Asian countries. My comments would be principally on this point.

1. One of the most interesting results of the paper lies in the finding that, if we limit ourselves in the sectors where the coefficients are significant, the dispersion of the productivity level is widening in 10 industries compared to 5 where the productivity dispersion is significantly narrowing. Thus, it can be said that widening productivity dispersion is relatively strong characteristics of the Korean industrial sectors. In the case of Japan, this trend is even more pervasive. However, on the other hand, the convergence analysis confirms that the catching-up effects by individual firms

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toward the national leading firms do exist so that the firms with lower productivity level has grown up more quickly than their higher productivity counter partners. These two findings provide us with seemingly contradictory stories, and may need further explanation. (It might be interesting to see the result from the same exercise with two the sector groups classified according to whether the productivity dispersion is widening or narrowing.)

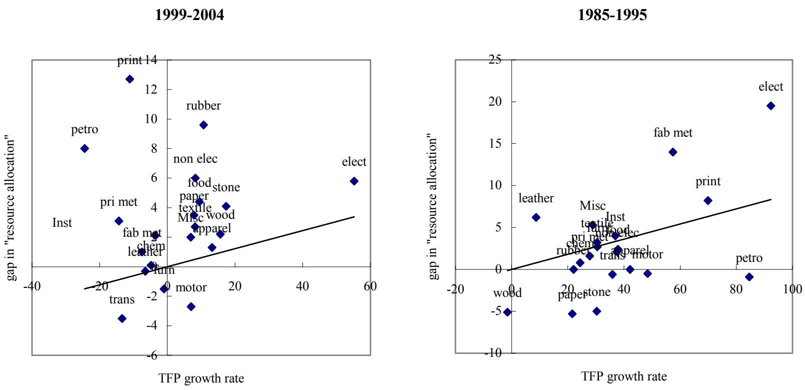
2. The finding that the productivity dispersion is wider in Japan than in Korea may reflect the fact either that Japan has a relatively stronger SME sector than Korea do or that the Japanese industrial structure is on a matured stage while Korea is on a growing stage so that the productivity growth at the industrial level is mainly determined by a few number of "superstars" in each industry. Although these two interpretations might be not unrelated, I think it is nevertheless interesting to see which one of the two is the more relevant interpretation. In order to see this, I would suggest to decompose the dataset by firm size, and to compare the differences within large firms, within small firms and between large firms and small firms. This might add an "institutional" explanation to the paper's finding.

3. It is also interesting to note the findings related to the pattern of convergence process of Korean and Chinese firms.

On the one hand, according to the result, while the Korean firms seems to benefit much more from the national leading firms for their knowledge source, Chinese firms are likely to utilize more foreign sources. The authors interpret that this result reflects the stagnant productivity levels of the leading Chinese firms. However, in my opinion, this explanation is not completely sufficient, given the fact that there should be still falling-behind firms and there is no reason for which these firms should not be able to benefit from the knowledge spill-over from the leading countries. Moreover, the productivity level of the Japanese leading firms do not seem grow fast either, while the catching-up *vis-à-vis* the national leading firms is almost as strong as the Korean firms. In my opinion, more adequate interpretation could be derived if the authors try to find some answer to this question based on the different learning mechanism of these two countries. For example, it might be completely possible that the interaction and knowledge spill-over amongst Korean firms are much stronger than the Chinese case, where the foreign direct investments are playing a crucial role in the productivity dynamics.

On the other hand, it is very interesting to note that, amongst the Korean firms, the "national" catching-up effect is stronger for low-performing firms in terms of TFP level, while the reverse is true in the case of the "international" catching-up. Although this is not the purpose of this paper, and that the evidence is not fully sufficient in order to develop this story, I think that this finding might provide us with an important contribution to the debate about how the international technology spill-over works. This result might be interpreted as indicating the "absorptive capability" at work. That is to say, while the low performing firms are capable to exploit "local" knowledge created by the local leading firms, only the best performing countries have the competence to exploit the knowledge emitted by the firms performing at the world frontier. This phenomenon is less evident in the case of China, but the most productive firms show still greater coefficient than the least productive firms. (Given that the least productive firms are excluded from the dataset, because it includes only listed firms, one cannot exclude the possibility of existence of "absorptive capability" effect even at the national level.)

4. The authors decomposed the sectoral TFP into the simple average and the "resource allocation" without further interpretation. This kind of exercise implicitly suggests that the market competition would help improving the TFP at the industry level. If the authors want to develop the paper in this way, I would suggest that they should be very cautious, because the decomposition analysis in general cannot tackle causality issue. For example, in looking at the Korea case, it is widely accepted that the market environment became more competitive after the financial crisis thanks to various structural reforms. However, as it can be shown the correlation between the TFP growth and the "resource allocation" is much less apparent in the period 1999-2004 than in the period 1985-1995. To answer why to this question would need a further reflection, but this might reflect the fact that the contribution of the "resource allocation" effect to the overall TFP growth is very limited, at least in the case of South Korea.



FIGURE

5. Finally, one minor comment: in examining the convergence between firms, it would be interesting to include the catching-up effect for Chinese firms toward Korean leading firms (not only toward Japanese leading firms). As the result shows that the coefficient for the productivity gap with the national leading firms become insignificant when the productivity gap with the Japanese leading firms, it can also change when the productivity gap with Korean firms are included (especially in Table 7).

In summing up, this paper provides us with an excellent contribution to the existing literature on the so-called “East Asian Miracle.” It shows a lot of very interesting and very insightful findings regarding the productivity dynamics in the Northeast Asian firms. Apart from its contribution, it also reveals a lot of very important questions which are necessary for a better understanding of the productivity dynamics for the firms of this region, and more generally for the catching-up countries in general.

*Comments by Yoshitsugu Kitazawa**

In this paper, a series of painstaking analyses is conducted on the TFP level, the TFP dispersion, and the catching-up effect, *etc.* for the listed companies of Japan, Korea, and China.

The micro-data used in this paper is not ubiquitous and difficult to obtain, and this paper carries out the first attempt to investigate the issues related to the TFP using the micro-data for the listed companies of Japan, Korea, and China.

This paper is esteemed in terms of the descriptions mentioned above.

However, some suggestions and questions remain in this paper.

From the results in Figure 3 and Table 5, it is concluded that the TFP rankings change frequently in the case of Korean firms. Further, this paper says that this is due to the dynamism in Korea. What is the dynamism? Describe the concrete examples for Korea and/or cite the papers analyzing the dynamism in Korea.

It is suspected that results in Table 5 reflect the difference of the regulations on the environmental problems among the three countries, especially for chemical industry. At least, the regulations are much stricter in Japan than in China. In Japan, the rise of the percentage of the highest decile seems to reflect the increasing strictness of the regulations over time, for the reason that the firms without overcoming the environmental problems by their constitutions cannot enjoy the high TFP levels. Conversely, it is suspected that the TFP rankings change frequently in China, thanks to the slack regulations.

In Tables 6 and 7, the panel data analyses based on the fixed effect model are conducted. Although the overall number of observations (I expect) is written in the tables, the number of time periods and the number of firms used in the estimations are not written. Write these numbers in the tables.

What do the notations $dAF_{JK}(t-1)$ and $dAF_{J}(t-1)$ denote in Tables 6 and 7? I cannot find the descriptions on these notations in this paper.

On the description "In the case of Japan, we may need both a

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stronger TFP growth of the national frontier firm and a stronger convergence effect for the lower-performing firms in order to improve the industry- or macro-level TFP." in page 14. Looking at the site:

http://www.dataranking.com/table.cgi?LG=j&TP=in01-2&RG=1&FL=
(Economics and Social Data Ranking, GDP per industry, Industrial part (including energy part)

The percentages of manufacturing sectors (without exactness in terminology) composing GDP are 30.3% for Korea and 25.2% for Japan in 1995 and 31.1% for Korea and 22.8% for Japan in 2005, respectively. The percentages of manufacturing sector are higher for Korea than for Japan, and they level out for Korea from 1995 to 2005, while decline for Japan. Accordingly, I think that many of the lower performance firms in terms of the TFP has shifted their directions to the other sectors (for example, the service sectors including the information and communications), being aware of their limitations in competing in the manufacturing sectors. I think that many firms with the lower performance start withdrawing from the manufacturing sector in Japan. I think that Korean manufacturing firms will experience the same situation as Japanese ones in near future, as the service sector grows.

As your future research, it would be advisable to conduct the analyses on issues related to the TFP and catching-up in the service sectors including the banking and entertainment industries for Japan, Korea, and China, using their micro-data. It may be that the intriguing results are obtained.